THE SOIL SCIENCE SOCIETY OF FLORIDA

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PROCEEDINGS
VOLUME XIV
1954

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Fourteenth Annual Meeting of the Society
Florida Citrus Building
Winter Haven
December 1, 2 and 3, 1954

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1955

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* Retiring Officers listed on page 212

ACKNOWLEDGMENTS

The Executive Committee of the Society wishes to take this opportunity to thank Commissioner Mayo and his associates most sincerely not only for the use of the splendid facilities at the Citrus Building in Winter Haven in which the meetings were held but also for their good assistance in so many other ways in making the meetings the success that they were. Reference in this is particularly to the good and faithful assistance of Mr. Charles Hughes, Supt. of the building.

The Committee also wishes to thank Mr. Harry Carrol, Manager of the Haven Hotel for his efficient and generous help with housing accommodations in cooperation with Dr. I. W. Wander who was in general charge of local arrangements; likewise to Mr. Nick Roubos who served the members and their guests a most excellent banquet at a most reasonable price in the Florida Room of the Citrus Building on the evening of 2 December.

No less grateful are the members of the Committee and those members of the Society who were privileged to be in attendance at the time for the opportunity of witnessing and hearing the inimitable Tom Moore Show "FLORIDA CALLING" which is broadcast from the stage of the Citrus Building at 11:00 A.M. each week day. This is a national attraction of the air for which a block of seats was reserved for the members of the Society. Thanks again to Tom Moore and his associates for this rare treat which, of course, was a unique experience to many if not most of those present. Also particularly appreciated was the extraordinary graciousness with which the regular broadcast was interrupted to announce the arrival into this good old world of ours of a brand new member of the Society, a spectroanalyst by profession, Master .... Fiskel, only a few hours before the broadcast began. This was accomplished, it was indicated, with the full and sympathetic cooperation of his parents, Dr. and Mrs. John G. A. Fiskel of Gainesville, the doctor having led a very complex symposium on the program of the previous day on "Minor Elements in Relation to Soil Factors," apparently with complete composure and without any evidence whatsoever of the impending event.

PHOSPHATE TOUR

Finally, our fullest possible appreciation and thanks are extended to the officials of International Minerals and Chemical Corporation, Bartow, for the splendid review they gave the large group that went on the tour of their phosphate operations. For plans and arrangements in this connection we are indebted to Mr. Frank Holland, Manager, Florida Agricultural Research Institute and Messrs. Tait and Enzer. The mining operations that were visited are among the most interesting and spectacular to be found anywhere in the country in showing how Florida phosphate is removed from open mines by tremendously massive equipment and processed in enormous quantities under very carefully controlled conditions that have ever in mind the conservation of phosphate resources as well as water which is used in immense quantities in an operation of this nature.

HONORARY LIFE MEMBERS

Alway, Dr. Frederick James, 1386 Grantham Street, St. Paul 8, Minnesota

Briggs, Dr. Lyman J., Director Emeritus, U. S. Bureau of Standards Department of Commerce, Washington, D. C.

DuPuis, Dr. John Gordon, M.D., 6043 N.E. Second Avenue, Miami 38

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Waksman, Dr. Selman A., Director, Institute of Microbiology, Rutgers University, New Brunswick, N. J.

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1954

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Florida Power and Light Company, Miami
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Hills, George B., Box 4817, 10 S. Laura Street, Jacksonville 1
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Jones, Luther, Belle Glade
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Rodaniche, Dr. A., Jr., Box 466, Ancon, Canal Zone
Russell, Robert P., 30 Rockefeller Plaza, Room 5101, New York 20, New York
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Southern States Land & Timber Co., Box 1551, West Palm Beach
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Thompson, Paul, Citizens Bldg., West Palm Beach
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Tiedtke, John, Shawnee Farms, Clewiston

Tilden, A. M., Box 797, Winter Haven
Tonner, Sidney, 500 Fifth Ave., New York 36, N. Y.
Trias, Jr., Ramon M., P. O. Box 3503, Habana, Cuba
Trueman Fertilizer Company, P. O. Box 1175, Jacksonville
Trumbull Construction Company, P. O. Box 382, Pittsburgh 7, Pennsylvania
United States Phosphoric Products, P. O. Box 3269, Tampa
United States Sugar Corporation, Clewiston
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Washington Technical Services, 810 18th Street. N.W., Washington 6, D. C.
Waverly Growers Co-operative, Waverly
Wilson-Toomer Fertilizer Company, P. O. Box 4459, Jacksonville
Woods, F. J. and L. P., P. O. Box 2721, Tampa
Yount, Fred C., 4845 Rolling Hills Road, Pittsburgh 27, Pennsylvania
Zipperer, J. O., P. O. Box 632, Fort Myers

CONTENTS

DEDICATION

BIOGRAPHICAL SKETCH — LYMAN JAMES BRIGGS

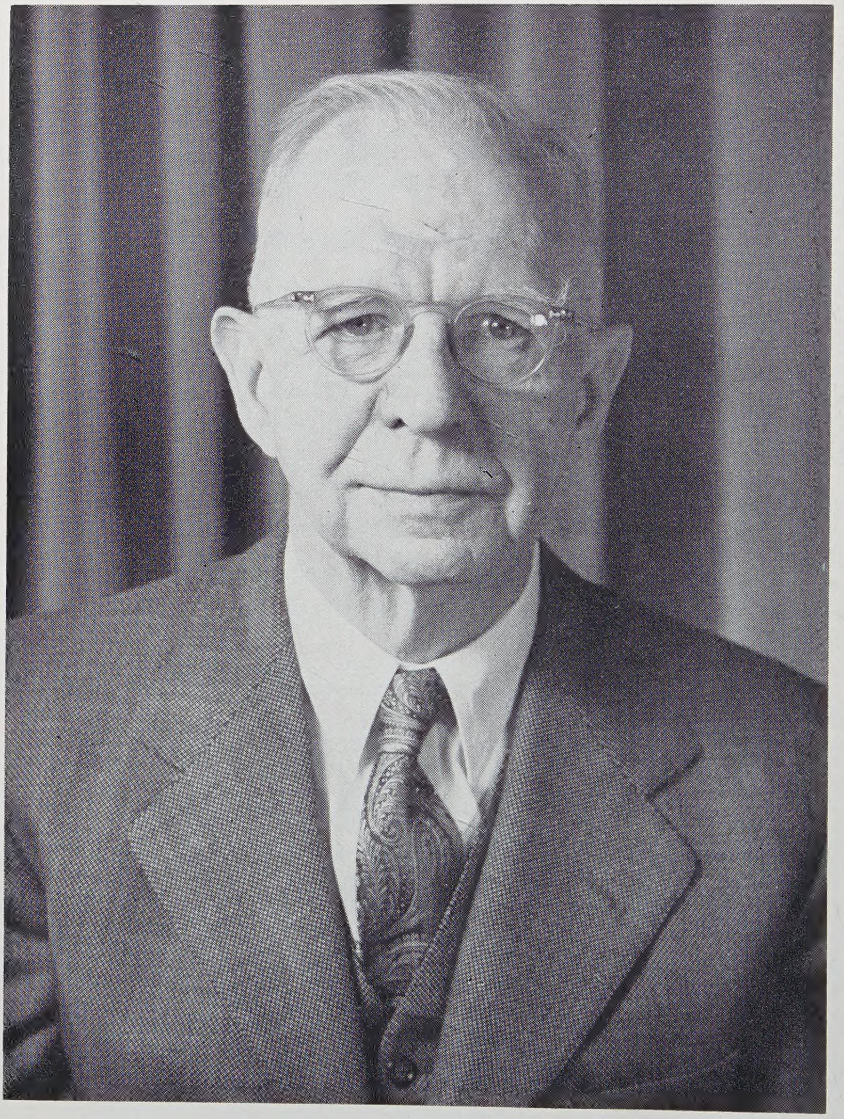
Lyman J. Briggs was born in Assyria, Michigan in 1874 and received his B.S. and M.S. from Michigan State in 1893 and 1895, respectively, and his Ph.D. from John Hopkins in 1901. He also was awarded an honorary Sc.D. by Michigan State in 1932, the D.E. degree from South Dakota School of Mines in 1935 and the ScD. degree by George Washington University in 1937.

From 1896 to 1906 Dr. Briggs served as physicist in the Bureau of Soils, U.S.D.A., and as physicist in charge of biophysical investigations in the Bureau of Plant Industry in the same department from 1907 to 1919, thus making a total of 23 years engaged in the agricultural sciences. It was during this period that his now famous work with soil moisture was developed in cooperation with Dr. H. L. Shantz that has given us the very useful method of determining the "moisture equivalent" of a soil that has proven so helpful to us in our work with Florida soils through the years.

In 1920 Dr. Briggs became chief of the Division of Mechanics and Sound in the U. S. Bureau of Standards in which position he continued until 1933. During this period he served simultaneously as assistant director of the Bureau from 1926 until 1933 when he became director of this most famous Bureau in all the world for the establishment of methods and standards for all types of measurements, procedures and processes.

In the course of his remarkably fruitful life of service in his chosen field of physics Dr. Briggs gathered memberships, chairmanships and directorships in so many important advisory committees, councils, boards, conferences, societies, associations and academies that it would be scarcely possible to enumerate them all in a brief statement of this type. Mention should be made, however, that he once shared the Magellan Medal; was president of the Washington Academy in 1918; was Director of the Washington Academy of Medicine in 1937 and President of the American Physical Society in 1938.

More recently, after having long since closed his active interest in agricultural research Dr. Briggs has been particularly concerned with aerodynamics and the aerodynamical characteristics of projectiles, bombs and aerofoils in a highspeed windstream; gyroscopic stabilization; acceleration of gravity at sea and properties of liquids under negative pressure. Quite recently he has published on such widely diverse physical subjects to those indicated above as "The Limiting Negative Pressure of Mercury in Pyrex Glass," and "The Limiting Thickness of an Electrolyzed Gas Film Capable of Sustaining a Given Negative Pressure," all of which gives credence to a remark by Dr. Brode on the occasion of his eightieth birthday (May 7, 1954) when he said "Upon his retirement from the position of Director of the National Bureau of Standards in 1945, after 45 years of government service, he gave up only administrative responsibilities and has continued active research and writing, as evidenced by his many technical articles since that time."



DR. LYMAN JAMES BRIGGS

In his kindly letter of acceptance of his nomination by the Society to Honorary Life Membership Dr. Briggs noted that his recent paper on the limiting negative pressure of water "resulted from a deep interest in the subject ever since the days when Shantz and I were working together." And he goes on to say "I am happy to learn that you have found the moisture equivalent method useful. I hoped at the time it would find its place along with mechanical analysis, which was so difficult to interpret."

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

ADDRESS REPLY TO
NATIONAL BUREAU OF STANDARDS
WASHINGTON 25, D. C.

IN YOUR REPLY
REFER TO FILE NO.

Mar 16, 1955

Dear Dr. Allison

I am glad to enclose another photograph, as you requested.

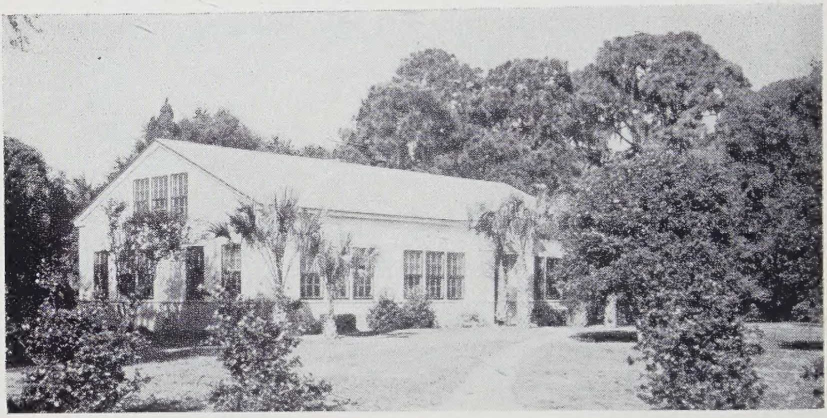
I regret the delay in answering your letter, but I have been away from my laboratory for some time

I wish to thank your Society for its generous tribute to my early work in soil physics

Sincerely yours
Lyman J Briggs

INTERIM (SPRING) MEETING

April 15 and 16, 1954



Office building of the Gulf Coast Experiment Station containing research offices, library, conference room, photographic dark room and business office.

The First Annual Interim Meeting of the Society was held on April 15 and 16, 1954, at the Gulf Coast Experiment Station (Bradenton) and Range Cattle Station (Ona). The purpose of these annual, interim meetings will be to study the soil and agronomic programs under investigation within the Florida Agricultural Experiment Stations.

On the opening day the group convened at the Gulf Coast Station. Following a review of the soils program under investigation by Drs.

Two year old grade Brahman steers grazing White clover-grass pasture at the Range Cattle Experiment Station, Ona. These steers made an average daily gain of 3.03 pounds for a 100-day period beginning January 1952.

Ernest L. Spencer, C. M. Geraldson, S. S. Wolz, and Mrs. A. J. Overman, tours were made of all experimental field plots and of the laboratory and greenhouse facilities. An evening barbecue was served by David G. A. Kelbert, Associate Horticulturist at the Station.

On the morning of the second day the group, under the supervision of W. Harper Kendrick, Agricultural Agent for Manatee County and J. R. Henderson, Extension Specialist in Agronomy, inspected several commercial operations showing clover pastures, ensilage storage and a vegetable-pasture rotation program.

Following a luncheon served on the grounds of the Experiment Station a tour was made of the experimental pastures and other facilities at the Range Cattle Station with Dr. Elver M. Hodges and D. W. Jones in charge.

COMPREHENSIVE REVIEW OF SOIL AND TISSUE TESTING

Ernest L. Spencer *

At the Thirteenth Annual Meeting of this Society in Gainesville last January, the program included a symposium on soil and tissue testing. Some of the members who heard this symposium felt that an effort should be made on this year's program to bring together the highlights of this symposium in the form of a comprehensive review. Our program chairman, Dr. Fred H. Hull, requested that I undertake this assignment, since I was program chairman last year and helped to organize this symposium.

The ten papers delivered at this symposium and published in the *Proceedings* were prepared by G. M. Volk; J. Fielding Reed; C. C. Thornton; V. E. Woods and R. K. Voorhees; O. C. Bryan; F. B. Smith; W. T. Forsee, Jr.; W. L. Pritchett, H. L. Breland and W. D. Hanson; C. T. Ozaki and G. D. Thornton. An introductory talk was given by J. R. Henderson, but was not presented for publication. Since time is limited, I will confine my remarks to those statements and ideas which I feel should be re-emphasized. Since these papers are all published in Volume 13 of the *Proceedings*, reference to specific authors will not be made in every case.

There are two approaches which might be followed in reviewing this symposium. One approach is a discussion paper by paper—but little can be gained from such a review, since the reader can readily do this at his own leisure. The second approach, and the one which I will follow, is the discussion of all ten papers under such general phases as (1) sampling, (2) chemical analysis of samples, (3) interpretation, (4) role of tissue testing, (5) general remarks and (6) conclusions. By following such an approach I can better co-ordinate the collective thinking of the various speakers on each of the several phases.

First, let us define the possible value of soil testing or analysis in our agricultural economy. As it was so well brought out, soil testing should provide research data on which can be based a fertility program for various crops grown in the major soil groups. With such a generalized fertility program serving as a foundation, it might then be feasible to proceed on a service basis and make adjustments where necessary in the fertilizer practice of individual growers.

The various ways in which this service to the individual is carried out in other Southern States were clearly described by Dr. Reed. Each of these states has its own system. In some states the experiment station is responsible for the entire program. In others, the service end of soil testing is in the hands of the extension service. In one state the service is operated by the state department of agriculture. There is also quite a variation in the method of financing the soil testing program. Some states support their programs by appropriations through their experiment

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* Soils Chemist in Charge, Gulf Coast Experiment Station, Bradenton.
Florida Agricultural Experiment Station Journal Series, No. 364.

stations, through their extension services, or through both. Other states charge a small fee as a token payment. In one state the program is financed by a slight increase in the state inspection tax on fertilizer. The method of handling soil testing also varies from state to state. Some states handle it through one central laboratory. Another system involves a central laboratory at the state university or experiment station with additional branch laboratories at substations. The program may be under the direction of the main station, but in some states each sub-station sets up its own program. Other states operate entirely through county laboratories. Variations of these systems occur in a few other states. Further mention as to which might be the most effective will be made later under general remarks.

FIELD SAMPLING

The first step in soil testing is taking the soil sample in the field. One of the inherent weaknesses of soil testing is the assumption that only the person taking the sample can know if the sample is representative of the field. The possible inability of even this person to recognize soil variability within a given area was brought out by several speakers. Particular mention should be made of the excellent discussion dealing with field sampling by Pritchett, Breland and Hanson. From their statistical study, they concluded that the number of borings needed would depend not only on the field variability but also on the determinations to be made on the composite sample.

CHEMICAL ANALYSIS

After the sampling is completed, the next question is what type of analysis should be carried out. The final answer to this question depends somewhat on the reasons for taking the sample in the first place. These reasons have been classified by Volk under such headings as research, fertility survey by soil types or groups, crop production service to the commercial grower, dooryard service for the householder and public relations. These groupings have been further sub-divided as to time of sampling, condition of the crop and the type of analysis to be made. This classification and grouping should help materially in orienting the various concepts of soil analysis.

Several different types of agencies now do soil testing work within the State of Florida. Such agencies may be classified as (1) commercial analytical laboratories, (2) laboratories operated by fertilizer companies for routine service to customers, (3) growers' research and consulting organizations and (4) state-supported laboratories. The facilities, analytical procedures and services rendered to the growers by each agency were described in detail by Thornton, Woods and Voorhees, Bryan and Smith.

In connection with this analysis phase, it was mentioned that soil-testing kits lack sensitivity in the lower fertility ranges where differences are most important for many crops. This makes them unsatisfactory for use in arriving at recommendations for fertilizer treatments. In the past, many kits were used because most quantitative laboratory methods were long and laborious. However, the advent of the flame spectrophotometer has simplified as well as increased the speed and accuracy of handling large numbers of samples.

INTERPRETATION

The third phase of soil testing, namely, interpretation of results, is by far the most important because it is the ultimate purpose of all soil testing. Unfortunately, as many speakers pointed out, this phase is the weakest link in the soil testing chain because of its complexity. The interpreter must consider not only the chemical analysis, but also (1) the physical structure, moisture relationship and nutrient-holding power of the soil, (2) the nutritional balance in the soil, (3) the antagonistic effects of one nutrient with another, (4) the nutritional requirements of the plant at various stages of growth, (5) drainage and irrigation, (6) season of year and (7) the time lag between sample collection and application of results. It is apparent, therefore, that the soil test is only a part of the information needed for a satisfactory fertilizer recommendation. In addition, there is no substitute for information gained through experience.

The inadequacy of our knowledge concerning the nutrient requirements of crops at various stages of growth was emphasized by several speakers. It is this lack of calibrated crop response data that makes it difficult to do a competent job of interpreting at the present time.

Dr. Forsee and his co-workers at the Everglades Experiment Station have shown what can be done in this connection by determining "threshold levels" of the nutrients required for several of the crops grown on the organic soils of the Everglades. With this information, more accurate fertilizer recommendations can now be made for these organic soils. The establishment of similar threshold levels should be worked out for the other major soil types within the State.

TISSUE TESTING

The value of tissue testing as a diagnostic tool and as a supplement to soil testing was mentioned by several speakers. In this connection, Reed states "Rapid tissue testing in the field has been used successfully in the midwestern states, but has never assumed its proper place in the South. Many agencies are sold on the possibilities of this tool, but the fact is that few of them have put it into actual operation in the field. One reason, of course, is that the person using it must be quite well trained in its use as well as in its interpretation. Because of this, it has not been too well used among the county agent group in the South. This tool is one that offers tremendous possibilities for extension specialists, branch station personnel, and other extension workers who will acquaint themselves with its use." Moreover, tissue testing serves as a measure of nutrient uptake and assimilation, as well as being an aid for diagnosing nutritional disorders in growing plants.

GENERAL REMARKS

In this section, I would like to give a few direct quotations from several of these symposium papers. These citations will assist us in co-ordinating our thinking on soil and tissue testing within our own State.

According to Volk, "The problem of evaluating soil testing in Florida is not one of a decision for or against the service as a whole, but rather one of degree of service in terms of the types of analyses justified for

different areas." He further states "The key to the problem in Florida lies in determining a factor of safety sufficient to cover all variation and then to ascertain if this is sufficient improvement over a standard recommendation to justify its use." Along this same line, Forsee states "In making fertilizer recommendations on the basis of soil tests, standard mixtures that most nearly fit the estimated requirements should be suggested rather than exact formulations. Standard mixtures are usually lower in price and more readily purchasable."

Let us go back for a minute to the chart prepared by Volk showing five reasons for soil testing. One of these reasons as you recall is labelled "public relation." May I call to your attention the brief statement by Volk dealing with this heading because I think it is a concept worthy of serious consideration. This statement is as follows: "Public relations could as well have been called educational opportunity. It is one of the most valuable phases of any testing service because it establishes a close contact between the grower and the agricultural specialist and allows for greater distribution of up-to-date crop production information even though the actual laboratory tests may or may not be of additional value to a grower."

Several speakers emphasized the need for a more intensive research and educational program. Thus Woods and Voorhees state "In attempting to run and interpret soil tests, we believe there is a dire need for the standardization of methods by all soil testing agencies as far as practicable. Also a more intensive educational program by the Experiment Station, Extension Service and other agencies on reliable methods of soil sampling and testing as correlated with crop response."

In this same connection Dr. Bryan states "A rational appraisal of the soil testing program in Florida indicates that the public agencies, such as the experiment stations and universities, can render a most valuable service to the industry and the future progress of the state, by expediting their effort to provide correlated crop response data to the different fertilizer nutrients on the major soil types. This is a long time program, but it is basically sound; and without such data, the best of trained and experienced workers cannot avoid error and confusion. Such information will provide practical methods of calibrating any standard extracting reagent for soil analysis and testing, and permit a needed flexibility for local soil problems. The relative cost of securing this type of information in other states is not very great, yet pays good dividends. In my opinion, this information takes precedence over all other data so far as soil analysis and testing is concerned."

Dr. Smith states in this connection "There is an urgent need for a new *approach* to the problem of calibration of tests, correlation of test results with response, and the interpretation of the test results."

These remarks would not be complete if reference were not made to a brief citation from Reed's paper concerning his idea of one of the best systems of soil testing. Following his summary of the various systems now being used in our Southern States, he concludes "If funds are not a factor in setting up a soil testing program, one of the best systems would appear to be that involving a central laboratory with one individual responsible for the entire program, but with laboratories also located in the branch stations and operated under the supervision of a person who devotes his entire time to the soil testing program in that area. That

person would have time to follow up work in his area and should be a sort of service agronomist for the section in which he operates. He could include tissue testing in his follow-up program and in time would become familiar with the farmers and the agriculture of the area."

CONCLUSION

As I bring this review to a close, I would like to add a comment or two which I hope all of us as research workers and agricultural specialists interested in soil testing will consider. While we are building up, through research and practical experience, the foundation for a sound soil testing program within the State, care should be taken to exercise the utmost caution in our interpretation of fertility requirements. Soil testing has a definite place in our agricultural economy but its present limitations must be recognized. No grower will expect us to have answers to all of his questions on soil fertility. He will readily accept and understand a straightforward "I don't know" as an answer when we are in doubt. We must not permit him to lose faith in the practical applications of soil testing by being misled through haphazard recommendations. When we don't know the solution to his particular problem, it may be possible to *suggest* a fertility practice that might be followed as a temporary measure. We should bear in mind continually that a superficial recommendation may be far worse than no recommendation at all, because it might be very misleading under some conditions.

SYMPOSIUM: MINOR ELEMENTS IN RELATION TO SOIL FACTORS

TOXIC EFFECTS OF ACCUMULATED COPPER IN FLORIDA SOILS

Walter Reuther and Paul F. Smith *

Between about 1945 and 1952, an increasing number of Florida citrus orchards on sandy, acid, well-drained soils became affected with a chlorotic foliage disorder suggesting iron deficiency. Observations indicated that prior to that time, such symptoms were confined largely to poorly drained areas and calcareous soils and were not a common orchard problem in Florida.

In studies of affected citrus orchards, beginning in 1947, it was observed that in the cases of severe chlorosis, the tree became unthrifty and yield was markedly reduced. It was soon found that the condition was associated with acid to very acid topsoil (about pH 5.5 to 4.0), which was almost devoid of healthy fibrous roots. Many dead roots were usually found, and the few living rootlets were abnormally dark-colored, stubby and poorly branched. Cover-crop growth in these affected orchards was generally very sparse, and some weed species also showed foliage chlorosis (18). The chlorotic citrus leaves were characterized by an abnormally low iron content (21). Subsequent observations indicated that varieties on sweet orange and grapefruit stocks are particularly susceptible to this acid-soil chlorosis, but that none are immune.

Comparison of a few preliminary analyses of the soil, foliage and fibrous roots from healthy and affected areas suggested the working hypothesis that the disorder was due, in a majority of cases, to a toxic effect of accumulated heavy metals, especially copper, in the topsoil, which, under acid conditions, injured fibrous roots, and interfered with their ability to take up nutrients, especially iron (19).

Supporting this hypothesis were previous studies involving the total analysis of the soil before and after 7 years of treatment with known amounts of phosphorus, copper, zinc and manganese. These indicated that under ordinary conditions, almost all, if not all of these elements were fixed in the upper one or two feet of soil of the Lakeland and related series (17). In the case of copper and zinc, all the metals applied could be accounted for in the top 6 to 9 inches of soil. Previous laboratory studies by Jamison (10) showed that copper was tightly fixed by sandy soils of the type commonly used for citrus culture. Subsequently, Wander (27) and Westgate (29) confirmed these findings in field studies.

Further support for this hypothesis was implied by the early work of Forbes (2). This classical study indicated that toxic levels of copper in the soil or nutrient solution caused stunting of top growth, "stripping

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and yellowing" (chlorosis) of the foliage and abnormal stunted root development of such plants as corn, bean, and squash. Forbes recognized, but did not demonstrate clearly, that toxicity of copper in the soil was influenced not only by concentration of copper, but also by the clay, organic matter, and carbonate contents of the soil. He showed that most soils fixed copper added from various salts and ores to a high degree. His analyses indicated that copper-stunted plants contained somewhat more copper in tops, but very appreciably more copper in roots than healthy plants. Further, he concluded from staining reactions of rootlet sections that the abnormal concentration of copper in injured roots was combined largely with plant proteins, especially those found in the pro-meristem zone of the growing corn root tips, and not with the epidermal tissue of the root surface. In addition, the work of Chapman, et al. (1) and others (6, 7, 8, 9, 29) indicated that copper and other heavy metals in toxic amounts could produce chlorosis and stunting of citrus and other plants.

Subsequent studies reviewed herein showed that this heavy-metal toxicity hypothesis for the cause of acid-soil chlorosis was substantially correct, but copper appears to be the only heavy metal present in toxic amounts in Florida citrus soils. Furthermore, the problem proved to have many other facets and ramifications.

Initial pot studies (18, 19) demonstrated that adding copper to very acid (below pH 5.0) old orchard soil produced iron chlorosis of citrus seedling foliage which was associated with abnormally dark, stubby, poorly branched fibrous roots having an abnormally high copper content (about 400 p.p.m. of Cu), which was located mainly in the cortex of root tips (24).

A survey (19) of the total copper content of the topsoil in more than 100 citrus orchards in Florida showed that there was a definite relation between the age of the orchard and the copper content. Correlation analysis revealed a low but statistically significant relation between copper content and the incidence of iron chlorosis, suggesting the copper was one of several factors involved. Mature orchards generally contained 50 to 250 p.p.m. of total Cu in the top 6 inches of soil. Comparable virgin top soils usually contained 1 to 10 p.p.m. (5, 19). The 6-12 inch depth of orchard soil usually contained less than 50 p.p.m. of copper, with about two-thirds of the samples from mature orchards assaying less than 25 p.p.m. Occasionally, appreciable copper was found at a depth of 18 to 24 inches when very acid conditions had prevailed in soils heavily fertilized with copper for many years. For example, in a very old orchard on a hammock phase of Lakeland fine sand, the profile was found to contain total Cu as follows: 0-6″, 197 p.p.m.; 6-12″, 57; 12-24″, 19; 24-36″, 5. Natively, this soil probably contained between 2 and 8 p.p.m. of Cu in the topsoil and between 1 and 4 p.p.m. in the subsoil. The exchange capacity of the 0-6″ horizon of this soil was 3.6 milli-equivalents per 100 grams of dry soil derived largely from the 1.97% of organic matter it contained. Simple calculations indicate that the 197 p.p.m. of copper would saturate about 17% of the exchange complex of the topsoil if all were in exchangeable form! Natively, the copper saturation of this topsoil probably was in the neighborhood of 0.4%. It is estimated that the exchangeable K in a soil like this, soon after heavy fertilization, would be at most about 150 p.p.m. in the topsoil (14), or about 11% of saturation.

Early studies by Hill and Bryan (8) indicated that mustard plants differed in their susceptibility to copper toxicity on various soil types, with the degree of toxicity from a given dose inversely related to the exchange capacity of the soil. Our studies with pot cultures of soils from chlorotic citrus orchards and comparable virgin areas indicated that pH, exchange capacity and phosphorus content of the soil all have an influence on the incidence of chlorosis and vigor of citrus seedlings subjected to toxic levels of copper in the soil (20). With soil near pH 5, citrus seedlings in pots began to show copper toxicity on common Florida citrus soils when the total copper level reached about 1.6 milligrams of Cu per milli-equivalent of exchange capacity in 100 grams of dry soil. At twice this level of total copper in relation to exchange capacity, mild to severe toxicity was likely to occur when the soil pH was in the range beween 6 and 4. Thus, acid, sandy soils of the Lakeland type having between 1.5 and 3.0 milli-equivalents of exchange capacity appear to be definitely unfavorable for normal growth of citrus seedlings in pots when they contain about 50 to 100 p.p.m. or more of total copper. Acid soils of the Eustis or Orlando type having an exchange capacity between 4 and 6 milli-equivalents are likely to produce a comparable degree of toxicity at about 125 to 200 p.p.m. of total copper.

Zinc and manganese in these concentrations did not appear to be toxic to citrus seedlings in pots (20). Solution culture studies (25) suggested that copper is about 50 times as toxic to citrus seedlings as manganese and 12 to 15 times as toxic as zinc, when compared on the basis of concentration in nutrient solution expressed as parts per million of the element. Sand culture studies by English workers, using oats as the indicator plant (9), indicated about the same order of relative toxicity of these three heavy metals.

Further pot studies indicated that when a soil contained a toxic level of copper, growth of citrus seedlings was progressively depressed as the soil became more acid. There appeared to be a rather sharp increase in toxicity as acidity was increased from pH 7 to pH 6 and then a more gradual increase as the acidity increased to pH 4 (20). Both field (19) and pot studies (20) suggested that one of the best practical means of reducing the toxic effects of high copper in citrus orchards is to apply sufficient lime or other basic material to bring the topsoil near pH 7. Thus liming, together with the application of chelated iron, appears to offer a fairly satisfactory means of practical control of the undesirable effects of high copper in most Florida citrus orchard soils. The timely discovery by Stewart and Leonard (13, 26) that chelated iron applied to acid soils in small amounts would effectively overcome iron cholorsis was a valuable contribution to the solution of the acid-soil chlorosis problem in Florida orchards. Their work suggested to us that a shortage of iron in the tissues is one of the primary pathological conditions produced by toxic amounts of copper in the soil. The work of Smith, *et al.* (22, 23, 24, 25) in solution culture showed that toxic levels of copper not only depressed iron concentration in leaves, but deranged the whole pattern of nutrient balance in them and caused stunting, thickening, lack of branching and abnormal dark coloration of fibrous roots. Chlorosis of the leaves of citrus seedlings growing in copper-toxic nutrient solution was controlled effectively by adding chelated iron but fibrous root development was not improved. Field studies by Ford, *et al.* (4) indicated

that chelated iron treatment of chlorosis citrus trees greatly improved root growth in the subsoil, but not in the high-copper topsoil under acid soil conditions. Similar results were obtained by Westgate (29), working with vegetable crops on high-copper soils. Thus, the evidence suggests that chelated iron treatment of affected plants does not antidote the pathological effects of high copper on fibrous root development, but does supply iron to the top.

Information obtained from our pot studies and field observations suggest that the topsoil is the principal source of available iron in some types of soil. On these, severe iron chlorosis of the foliage and poor vigor and productivity are likely to result from a high level of copper when the topsoil becomes acid, particularly if the phosphorus concentration is also high. In such situations, applications of chelated iron are spectacularly effective in quickly controlling foliage chlorosis, but complete recovery of normal vigor and productivity may not result from this treatment alone. Heavy liming or sodium carbonate treatment will also be required to correct the acid soil condition, and permit the development (usually a gradual process) of more normal fibrous roots in the high-copper zone of the soil. In other soil types having a high level of available iron in both topsoil and subsoil, a toxic level of copper in the topsoil may not result in foliage chlorosis, but simply in reduced tree vigor and efficiency proportional to the extent of root injury. Chelated iron is of little value in treating this latter condition, but heavy liming usually will produce marked improvement, if not complete recovery, and the recovery process may require more than one season. Recovery may be incomplete if the copper level in the soil is too high, because the higher the copper level, the less effective is heavy liming in reducing toxicity (20). In certain situations, heavy liming may produce complicating factors such as deficiencies of zinc and manganese which must be dealt with to effect complete recovery. Of course, many soils will fall in a position intermediate between these two extremes with respect to iron availability and response to treatments.

Citrus seedlings growing in virgin soil of the Lakeland, Orlando and related series did not develop appreciable iron chlorosis of foliage throughout a wide range of copper and pH treatments (20). In virgin soils, copper toxicity was manifested by poor root development, stunting of top growth and foliage symptoms suggesting nitrogen or phosphorus deficiency. Similar results were obtained by Reitz and Schimp (15). In old orchard soils, on the other hand, citrus seedlings usually produced distinct symptoms suggesting iron chlorosis of the foliage in response to toxic amounts of copper. Despite the greater incidence of foliage chlorosis in high-copper old orchard soil, stunting of root and top growth was distinctly less than that obtained in analogous virgin soil adjusted to an equivalent level of added copper (20). On the basis of this observation, it was postulated that some factor or factors present in old orchard soil, possibly high phosphate, reduced the toxicity of copper (20). Previous studies with long-term field plots showed that Valencia orange trees heavily fertilized with superphosphate over a period of years contained less copper in leaves than those of trees receiving little or no superphosphate during the same period (16).

Subsequent pot studies (unpublished) with seedlings growing in soils obtained from high-phosphate and no added-phosphate plots in several

long-term field trials demonstrated that the residual effects of heavy phosphate fertilization in orchards did reduce the toxic effect of copper in the range common in old orchard soils. Similarly, the addition of large amounts of tricalicum phosphate to virgin soil reduced the toxicity of added copper. However, when sufficient copper was added to such soils to almost completely inhibit growth of citrus seedlings, a high added or residual phosphate level did not reduce toxicity. These studies showed also that high phosphate increased copper-induced iron chlorosis of citrus seedlings under acid conditions in most, but not all, soils tested.

It is clear from these studies that all of the difference in toxicity produced by equivalent levels of total copper in virgin and old orchard soil cannot be accounted for by the residual effects of heavy phosphate fertilization in old grove soils. It is now postulated that copper added to the soil may in the course of normal soil reactions over a period of time become fixed in more stable, less soluble, and less toxic forms. Hence, comparison of a given level of total copper accumulated over a period of years in old orchard soil, with an equivalent level of freshly added copper in a comparable virgin soil, may not lead to definite conclusion concerning the possible cumulative effects of fertilization or other cultural factors on toxicity of copper. It was observed by Hill and Bryan (8) that toxicity of copper added to the soil decreased with time after application, but no substantiating data were presented.

It seems likely that copper added to soil forms insoluble complexes with organic matter in the soil (10, 12). The toposil of most soils used for citrus culture in Florida are essentially organic soils highly diluted with sand (11). It is easy to envision that copper may be held by covalent or chelate linkages with greater security by some of the products of organic matter decomposition than others. In the course of the formation of the more stable humus fractions it is possible that progressively more copper is bound in the tighter complexes as the normal soil reactions proceed with time and fluctuating environmental conditions. In addition, it is possible that progressive fixation of copper by the clay fraction may proceed gradually as a result of entry into the lattice of the clay crystals through wetting and drying, or some other mechanism. Still another factor which may contribute to the amelioration of toxicity of copper in old orchard soils is the possible antagonistic effects of manganese and zinc (13). It has been shown that these ions, as well as phosphate, tend to accumulate in Florida orchard soils (17, 27).

Clearly the factors affecting the availability of copper and the other heavy metals in Florida soils need further investigation. Such studies should encompass the entire range from deficiency to toxicity. They should include an investigation of the role of the humus and clay fractions in fixation and accumulation and the possible antagonistic effects or other interactions with cations and anions added in fertilizers.

Of course, responses obtained with seedlings growing in pots do not always parallel the responses obtained with trees in orchard soils. In the pot studies reviewed herein the entire root system of the seedling was confined to a soil having a uniform copper content. The accumulation of copper in orchard soils has been shown to be confined largely to the top 6 inches (19, 27). This is only a minor portion of the principal root zone in most Florida orchards. Studies by Ford (3) showed that more than two-thirds of the fibrous roots normally occur in the subsoil

in most mature groves located on the deep sandy soils of the Lakeland and related series. Some fibrous roots are commonly found at a depth of 10 feet or more. Undoubtedly the toxic action of copper on the plant as a whole is far greater when the entire root system is confined in a high-copper soil than when only a portion is subjected to such unfavorable conditions. Thus, pot studies are useful for evaluating the favorableness of a particular portion of the soil root zone for root growth, and for clarifying some of the factors influencing the toxic action of copper. It is obvious that growth behavior of seedlings in topsoil samples does not indicate directly the probable response of an orchard tree having a major portion of its roots deep in the subsoil. These pot studies, together with the work of others (3, 28), suggest that too much emphasis has been placed in the past on the analysis of the relatively small topsoil fraction of the principal root zone in the deep sandy soils used for citrus culture in Florida.

In summary, the studies reviewed indicate clearly that there are definite limits to the amounts of heavy metals, especially copper, that can profitably be added to our Florida soils. Toxic amounts of copper are already to be found in certain acid, sandy orchard and vegetable soils. In the future, disease control and soil fertility research with these elements should evaluate carefully their residual effects in soils.

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MINOR ELEMENT RESPONSE OF VEGETABLES AT SANFORD: A REVIEW

Philip J. Westgate *

The Sanford truck crop area in Seminole County includes approximately five thousand acres of farm land devoted primarily to winter vegetables. This area started with the production of celery a little over half a century ago, and celery has been a major crop ever since. Recently, considerable diversification to other crops has taken place.

Leon fine sand, which has a hardpan two or three feet below the surface, is predominant. The soils were originally very acid (pH 4.5), but are usually maintained at or near pH 6.0. Artesian wells and subsurface tiling are used for irrigation and drainage.

Responses to the major elements, nitrogen, phosphorus, and potassium long have been known, and three or more tons per acre per crop of a complete fertilizer, such as a 4-7-5 or 5-5-8 formulation, have been the rule rather than the exception.

The calcium requirement usually has been taken care of by the application of liming materials such as wood ashes, lime, or dolomite. Excess fertilizer salts are associated with blackheart of celery, and have been shown to interfere with the uptake of calcium by the plant, even though considerable calcium is in the soil (6, 9). Blackheart of celery may be controlled by the application of soluble calcium as a spray to the hearts of the plant (1).

Magnesium deficiency of celery has been noted when this plant nutrient was left out of the fertilizer (5). This deficiency is corrected easily by the application of dolomite or magnesium sulfate to the soil. Celery fertilizers in this area usually contain approximately three percent magnesium (MgO).

The sulfur requirement of truck crops probably has been furnished by the various sulfates in the fertilizer materials, particularly in superphosphate. No nutritional response has been noted to additional amounts of sulfur.

The first minor element work at Sanford was the pioneer research of Purvis and Ruprecht (3) on boron, the lack of which causes cracked stem of celery. Ten pounds of borax per acre per year, applied either as a spray or in the fertilizer, corrected this deficiency. Today, cracked stem of celery is rarely seen in celery fields unless boron has been omitted.

Purvis and Ruprecht (2) using a combination of manganese sulfate, zinc sulfate and cobaltous chloride obtained increased yields of celery on two farms, but these same chemicals gave no response when used separately. Additional work with various mixtures of manganese, zinc, cobalt, and copper failed to increase total yields of celery, but did increase the incidence of blackheart (4). Manganese sulfate at approximately fifty pounds per acre has been used by celery growers where the

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soil reaction has been high enough to interfere with the availability of manganese.

Copper as a nutrient has failed to give favorable response in old vegetable fields in the Sanford area. In fact, additional copper reduces growth and increases iron chlorosis in many crops. This is understandable when it is realized that years of use of copper sprays for fungus control have resulted in concentrations of 200 to 500 p.p.m. of total copper (Cu) in the top soils of these farms (7).

Iron deficiency is of common occurrence in old vegetable fields. Whitner (10) controlled chlorosis of gladioli by spraying the plants at weekly intervals with from one to two pounds of ferrous sulfate in one hundred gallons of water per acre. Efforts to correct iron chlorosis with ferric or ferrous sulfate applied to the soil of these same fields have all resulted in failure.

Chelated iron, as the ferric salt of ethylenediamine tetraacetic acid (Fe-EDTA), has been found to correct iron chlorosis of numerous truck crops and ornamentals, even in the presence of high total copper in the soil (8). One pound of Fe-EDTA (12% Fe) in one hundred gallons of water per acre, applied as a foliar spray, or twenty pounds per acre applied to the soil, are giving control of iron chlorosis of numerous vegetables and ornamentals. The fact that the trisodium salt of EDTA, which contains no iron, also will correct iron chlorosis when applied to these soils shows that the unavailability of the iron, rather than a lack of iron in the soil, brings on the chlorosis.

Although molybdenum deficiency of citrus has been corrected in this general area by one pound of ammonium molybdate per acre as a spray, no molybdenum deficiency symptoms of vegetables –such as whiptail of cauliflower—have been noted in the old celery fields. No response has been received from the application of molybdenum to various vegetable crops, either as a spray or soil application. As has been the case with other minor elements, small quantities, sufficient for normal plant growth, undoubtedly have been added as impurities in the various fertilizer materials.

SUMMARY

In addition to response to the essential elements N, P, K, Ca, Mg, and S, truck crops (including celery) on Leon fine sand in the Sanford area have been shown to respond to boron and chelated iron (Fe-EDTA) either as foliar sprays or soil applications. Iron chlorosis of plants has been corrected by foliar sprays of ferrous sulfate, but not by soil applications of this iron compound. Other minor elements have not given response.

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THE TOTAL MANGANESE, COPPER AND ZINC CONTENT OF SOILS USED FOR CITRUS PRODUCTION IN FLORIDA

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Several investigators have studied the adsorption and retention of added manganese, copper and zinc in the sandy soils used for citrus production in Florida. Peech (4) found a large proportion of both copper and zinc fixed by Norfolk fine sand (now classified as Lakeland fine sand), with the copper fixed more strongly than the zinc. Further work by Jamison (3) substantiated Peechs' observations. Jamison further stated that, as far as their chemistry is concerned, these sandy soils may be considered organic in nature, since the accumulated 1.5 to 2.0 percent organic matter accounts for the major portion of their fixing capacity. Hasler (2) had found a differential of retention in organic soils and stated that copper was held more tightly than zinc and zinc more tightly than manganese. Erwin (1), in a lysimeter experiment using Norfolk fine sand, found that less than 1% of the total copper added was leached during a period of about 8 months. Available information regarding the retention of manganese in these sandy soils from work done by Peech (4) and Wander (8) indicates that retention is largely influenced by soil reaction. Reuther et al., (6) have reported considerable accumulation of manganese, copper, and zinc in citrus orchards 20 years of age or older.

With this background, soil analyses were made for total manganese, copper and zinc in soil samples taken in the same experimental block at the beginning and at the end of 15 years of treatment with fertilizers and sprays containing manganese, copper and zinc.

The analyses, given in Table 1, show the total amounts of manganese, copper and zinc in the soil at the 0-6 and 6-12 inch depth in 1937 and again in 1952 where the soil reaction was and was not controlled. The data given in Table 2 indicate that where the soil reaction was controlled at between pH 5.5 and 6.0, 90% of the copper, 69.5% of the manganese and 63.5% of the zinc applied during the 15-year period can be accounted for in the top six inches of soil. Where the pH was not controlled (4.3), 98% of the manganese was leached from the top six inches of soil. About 93% of the zinc was leached, but nearly half of the copper (46%) was retained. Analysis for copper of the soil profile down to the clay layer (8 feet in the area sampled) reflects the effect of the pH of the top soil. The data given in Table 3 shows that all soil depths under no pH control contain more copper than the corresponding depths under pH control. This indicates the downward leaching of copper under acid conditions. Analyses for manganese and zinc show the reverse condition, however, with more being present in the 6-12 inch layer under controlled pH conditions than under acid conditions. Evidently both manganese and zinc are more readily leached from subsoil than is copper.

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Further evidence of the effects of soil pH on retention of these elements is given in Table 4. The results shown were obtained by analyzing samples taken from different locations with respect to the trunk of the tree, since it was known that such samples vary greatly in reaction (5).

TABLE 1.—POUNDS PER ACRE OF MANGANESE, COPPER AND ZINC ACCUMULATED OVER 15-YEAR PERIOD WHERE SOIL REACTION WAS AND WAS NOT CONTROLLED. BLOCK 9—C.E.S.

Mn				Cu				Zn			
pH Control pH = 5.7		No Control pH = 4.3		pH Control pH = 5.7		No Control pH = 4.3		pH Control pH = 5.7		No Control pH = 4.3	
Soil Sample Depth											
0-6″	6-12″	0-6″	6-12″	0-6″	6-12″	0-6″	6-12″	0-6″	6-12″	0-6″	6-12″
1937											
6.9	2.9	6.1	3.9	6.1	1.9	6.6	1.4	6.9	4.3	6.1	2.3
1952											
371	12	15	6	460	19	239	50	80	24	15	10

It is thus well established that at a pH of 5.5 to 5.7 about 30% of the applied manganese and zinc, but only about 10% of the applied copper, leaches from the 0 to 6 inch layer of sandy soils used for citrus. It is also apparent that copper is retained to a greater extent by the soil and at a lower pH level than is manganese or zinc.

TABLE 2.—ADDITION AND PERCENT RETENTION OF MANGANESE, COPPER AND ZINC OVER A 15-YEAR PERIOD WHERE SOIL REACTION WAS AND WAS NOT CONTROLLED. BLOCK 9—C.E.S.

Element Additions Lbs./A. Over 15-Year Period						Percentage of Retention Under pH Control and No Control Depth 0 - 6″					
Mn		Cu		Zn		pH Control pH = 5.78			No Control pH = 4.3		
Fert.	Spray	Fert.	Spray	Fert.	Spray	Mn	Cu	Zn	Mn	Cu	Zn
449	74	397	107	38	77	69.5	90.0	63.5	1.7	46.0	7.8

From the information and indicated trends obtained on the Station plots, it was believed advisable to obtain similar information from commercial groves selected from several important citrus producing regions of the state. Such a sampling was made possible through the cooperation of men,[1] located in five important citrus producing areas, who are con-

[1] The soil samples and records of chlorosis symptoms were obtained through the cooperation of Dr. R. M. Pratt and his field assistant in the following areas: (1) Avon Park area—J. B. Weeks, (2) Ridge area—T. B. Hallam, (3) Tavares area—John Davis, (4) Indian River area—H. Holtsberg, (5) West Coast area—K. Townsend.

tinuously checking key groves for insect populations. These observers also keep records of nutritional deficiency symptoms as evidenced by leaf patterns.

TABLE 3.—EFFECT OF SOIL REACTION ON LEACHING OF COPPER.

Block 9—Plot 4				Block 9—Plot 5			
Sample No.	Depth in Inches	pH	Cu Lbs./A.	Sample No.	Depth in Inches	pH	Cu Lbs./A.
1535	0-6	5.65	545.0	1546	0-6	3.90	172.0
36	6-12	4.80	10.7	47	6-12	4.10	73.6
37	12-18	4.60	2.3	48	18	3.95	44.0
38	18-24	4.35	2.5	49	24	3.95	18.2
39	24-36	4.20	1.4	50	36	4.00	14.2
40	36-48	4.30	0.5	51	48	4.1	6.9
41	48-60	4.40	1.4	52	60	4.2	4.3
42	60-72	4 50	0.7	53	72	4.45	4.5
43	72-84	4.27	2.0	54	84	4.25	5.0
44	84-96	4.00	1.5	55	96	4.10	6.0
Block 9—Plot 9				Block 9—Plot 8			
1570	0-6	5.90	422.0	1558	0-6	4.00	150.0
71	12	5.05	16.5	59	12	4.15	58.4
72	18	4.90	25.0	60	18	4.20	25.0
73	24	4.35	2.2	61	24	4.05	18.5
74	36	4.32	2.5	62	36	3.92	10.5
75	48	4.35	1.5	63	48	3.95	7.2
76	60	4.40	1.2	64	60	4.02	6 5
77	72	4.45	1.0	65	72	4.15	5.2
78	84	4.35	3.0	66	84	4.05	4.5
79	96	4.40	2.2	67	96	4.10	11.8

TABLE 4.—EFFECT OF SOIL REACTION ON RETENTION OF APPLIED* MANGANESE, COPPER AND ZINC IN THE 0-6 INCH LAYER OF LAKELAND FINE SAND.

Sample Location	Soil Reaction	Pounds per Acre Mn	Pounds per Acre Cu	Pounds per Acre Zn
No pH Control				
Under Tree	3.6	13.7	140	15.5
Under Drip	4.2	13.7	195	33.0
Under Middle	4.6	45.0	237	41.0
pH Control				
Under Tree	5.0	137	358	35.0
Under Drip	5.6	494	496	94.0
Under Middle	6.0	590	560	152.0

* The amounts of manganese, copper and zinc applied were the same as shown in Table 2.

The five areas included in the survey are designated in the following manner: (1) Avon Park; (2) Ridge; (3) Tavares; (4) Indian River; and (5) West Coast. A total of 131 groves were sampled and the soil reaction, organic matter, total manganese and total copper determined. Total zinc was run on part, but not all, of the soil samples obtained in the survey.

RESULTS OF SURVEY ANALYSES

A summary of the survey analyses is presented in Table 5 with analyses for the individual groves given in the appendix. This information, when compared to analysis of soil samples taken in 1937 at the Citrus Station in an area which had not yet received manganese, copper and zinc, shows very plainly the considerable retention of these elements. Although no complete fertilizer record is available for these commercial groves, it would appear that in most cases the most important factor affecting the amounts of manganese, copper and zinc to be found is the amounts which have been used. If the same amounts of the three elements had been used in all areas for the same length of time, the soil type and reaction maintained would have been dominant factors in their retention. There is no question about the fact that where large amounts have been used relatively large amounts are retained in these sandy soils.

TABLE 5.—The Average Highest and Lowest Total Amounts of Manganese, Copper and Zinc in Pounds per Acre Found in Several Citrus Producing Areas of Florida.

Element	Location				
	Avon Park	Ridge	Tavares	Indian River	West Coast
Ave. lbs./A Mn	122	121	122	90	144
Ave. lbs./A Cu	171	173	112	171	129
Ave. lbs./A Zn	53	60	64	64	58
Highest Mn	414	215	288	234	313
Lowest Mn	11	45	23	3	13
Highest Cu	355	365	288	562	430
Lowest Cu	34	96	32	53	36
Highest Zn	87	88	120	128	137
Lowest Zn	26	35	24	23	21

The adverse effect of excess amounts of copper in sandy soils on the growth of citrus has been shown by Reuther and Smith (7). This effect is evidenced by an iron chlorosis under acid (below pH 5.0) soil conditions and by poor root development. Since monthly observations for chlorosis symptoms had been made for the past 28 months (July 1950-November 1952) in the groves sampled, a correlation between the amount of copper found and the observed incidence of chlorosis was attempted. This was done by calculating the correlation coefficient between a summation of chlorosis observations and the total soil copper. When such calculations were made on the basis of area, soil reaction, or total copper, no significant correlation was found (Table 6). This indicates that the observed chlorosis in the majority of cases in these commercial groves is due to some other factor or factors than to accumulated copper. This

does not mean that excess copper cannot cause chlorosis but simply that in most cases the amount of accumulated copper is not the major factor resulting in chlorosis.

TABLE 6.—CORRELATION COEFFICIENTS RELATING OBSERVED CHLOROSIS TO AREA, SOIL REACTION AND TOTAL SOIL COPPER.

Area	r Value Found	r Value Required at 5% Level
West Coast	.343	.388
Indian River	.068	.374
Tavares	.079	.349
Ridge	.077	.468
Avon Park	.158	.381
pH Level	**r Value Found**	**r Value Required at 5% Level**
4.55 - 4.95	.148	.514
5.00 - 5.45	.062	.270
5.50 - 5.95	.025	.294
6.00 - 7.00	.493*	.433
Copper Level	**r Value Found**	**r Value Required at 5% Level**
0 - 75	.210	.388
76 - 150	.112	.273
151 - 225	.246	.344
226 - 300	.031	.576
301 - 562	.069	.707

* Significant at 5% level.

The amounts of manganese and copper usually applied to the soil and zinc applied as a spray to correct or prevent deficiencies in citrus is much greater than the amounts removed by the crop. Typical fruit analyses for manganese, copper and zinc show that a 700-box-per-acre yield will remove about .04 pound of manganese, .04 pound of copper and .06 pound of zinc. If 20 pounds of a 4-6-8-3-1-½ fertilizer [2] is used in the summer and fall applications and 10 pounds of 8-0-8-6-2-1 used in the spring per tree, then 31.5 pounds of manganese and 16.8 pounds of copper would be added per acre during the year in the fertilizer. If a nutritional spray containing 3 pounds of zinc sulfate (36% Zn) per 100 gallons is used at the rate of 18 gallons per tree, 13.6 pounds of zinc would be added per acre. In addition, where a melanose spray containing .75 pound of metallic copper per 100 gallons is used at the rate of 15 gallons per tree, another 7.8 pounds of copper per acre will be added.

Thus a total of 31.5 pounds of manganese, 24.6 pounds of copper and 13.6 pounds of zinc are added per acre per year with only .04 pound of manganese, .04 pound of copper and .06 pound of zinc being

[2] Percent N; P_2O_5; K_2O; MgO; MnO; CuO.

removed in the crop. This is approximately 800 times as much manganese, 600 times as much copper and 200 times as much zinc as is required to produce a crop at the above rates of fertilization and production. Since it has been established that, where the soil reaction is maintained at between pH 5.5 and 6.0, all three elements accumulate, it would appear not only wasteful and extravagant but possibly even detrimental to continue adding each year manganese and copper in amounts so greatly exceeding utilization and leaching.

To understand the relationship between the amount of copper required for adequate nutrition on different soils and the amount resulting in toxicity, it is necessary to consider the organic matter and the pH of each particular soil. Theoretically, on a pounds-per-acre basis, each percent of organic matter in these sandy soils could combine with 1.272 pounds of copper. Thus a soil which ran two percent organic matter, as do many of the ridge soils growing citrus, could combine with 2.544 pounds per acre of copper to a six-inch depth. It is not known what percentage of the copper held by the organic matter is available, but from the apparent tenacity with which copper is held it is evident that a considerable amount must be supplied before sufficient is available to tree roots. Until the availability to citrus of copper held in the organic form found in these soils can be determined, estimations based on observation are the best guide. On this basis, about 2 percent of the organic matter should be saturated with copper before sufficient copper is available for citrus nutrition. Thus a soil containing 1 percent organic matter should contain about 25 pounds per acre total copper. This will increase to 50 pounds per acre at 2 percent organic matter, 75 at 3 percent organic matter and 100 pounds per acre at a 4 percent level of organic matter in the soil. These values are based on a soil reaction of pH 5.5 to 6.0, because at higher soil reactions probably less copper would be available.

Since zinc is used for the most part in a nutritional spray, and as a consequence in smaller amounts, it does not present as great a problem from the standpoint of accumulation. Also, zinc is less tightly held by the soil organic matter than is copper.

It should be pointed out, however, that in starting and growing a young grove the use of manganese and copper in the fertilizer and zinc as a spray is essential, since most virgin Florida soils are deficient in these elements. After the corrective amounts of these elements have been added to the soil, amounts used for maintenance (that is amounts required to replace losses by leaching and production) can be greatly reduced. It is estimated that between 50 and 100 pounds per acre each of total manganese and copper will maintain citrus trees in good growth and production under Florida conditions. It is believed that a soil analysis for total manganese and copper will indicate the necessity for a corrective program where larger amounts of manganese and copper are required or for a maintenance program where smaller amounts are required.

CONCLUSIONS

1. Where the soil reaction was controlled at between pH 5.5 and 6.0, 90% of the copper, 69.5% of the manganese and 63.5% of the zinc was retained in the 0-6 inch soil layer from applications made during a 15-year period.

2. Where the soil reaction was not controlled, pH 4.2-4.5, 46% of the copper, 7.8% of the zinc and 1.7% of the manganese was retained in the 0-6 inch soil layer from applications made during a 15-year period.

3. A survey of 131 commercial groves from all parts of Florida indicated considerable accumulations of total manganese, copper and zinc in the soil when compared to the amounts found in soil samples taken in 1937 before these elements were widely used in fertilizers.

4. There was no significant correlation between the total copper found in soils from commercial groves and the incidence of chlorosis, although it is known that under special conditions excessive amounts of copper can result in chlorosis.

5. Since nutritional requirements and leaching losses of manganese and copper are small (where the soil reaction is controlled) in comparison to the usual additions in fertilizers and sprays, it would be advisable to greatly reduce their use in old bearing groves, especially where they have been used for a number of years.

6. It is necessary to use manganese and copper in fertilizers for starting and growing a young grove, but after soil corrections have been made the amounts used for maintenance can be greatly reduced.

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APPENDIX

The Soil Reaction, Percent Organic Matter, Observations of Leaf Chlorosis, and Total Pounds per Acre of Manganese, Copper and Zinc Found in Individual Groves in Five Citrus Producing Areas.

Ridge

Sample No.	Grove No.	Lbs./A Mn	Lbs./A Cu	Lbs./A Zn	pH	% O.M.	No. of Chlorosis Observations	
							New Leaves	Old Leaves
1364	115	83.0	174.0		5.55	.96	8	6
1365	119	145.0	220.0	57.2	6.05	.83	0	0
1366	121	85.0	112.0		5.50	1.41	8	6
1367	122	108.0	186.0		5.25	2.10	7	6
1368	130	54.0	116.0		5.20	1.52	9	3
1369	131	125.0	146.0		5.90	1.44	1	2
1374	113	133.0	164.8		5.50	1.22	0	3
1375	110	215.0	248.0	88.0	5.70	1.07	8	3
1376	111	117.0	105.2		5.65	1.28	2	0
1377	112	102.0	159.2		5.50	.73	6	0
1378	116	140.0	184.0		5.25	1.11	2	0
1379	123	151.0	365.0		5.50	1.36	4	2
1380	124	117.0	222.4		5.90	1.25	2	0
1381	125	71.0	96.0	35.0	5.05	1.33	3	0
1382	126	151.0	216.0		5.30	1.91	0	2
1452	114	166.9	128.8		5.65	.77	3	0
1453	117	169.8	124.0		5.75	.86	1	0
1454	118	45.0	147.2		5.60	1.35	8	0

Indian River

1455	200	23.2	58.0	23.0	4.55	1.93	5	7
1456	224	62.4	75.2	37.0	6.50	.97	6	2
1457	226	137.8	280.0		5.70	1.88	6	4
1458	229	191.8	363.0	59.8	5.40	1.26	5	3
1459	230	76.9	53.2	25.8	5.42	1.67	3	22
1460	244	218.9	317.0		6.02	2.67	9	1
1461	250	198.9	255.0	79.0	5.60	1.18	10	9
1462	252	68.2	72.0		5.60	1.16	4	2
1463	253	120.2	108.4		5.58	1.26	4	1
1464	254	207.8	190.0		5.60	1.31	8	13
1516	201	80.0	245.0		6.45	2.28	7	6
1517	202	25.5	88.0		5.30	1.39	1	2
1518	206	16.0	65.0		6.22	3.74	5	3
1519	211	13.0	63.2		5.62	2.59	8	4
1520	214	3.0	80.0	56.5	4.80	6.08	6	2
1521	216	11.0	76.0		7.15	2.10	9	4
1522	231	8.5	465.0	128.0	5.10	5.46	5	5
1523	203B	66.0	83.2		5.40	2.80	2	0
1524	204	159.8	99.2		5.15	1.79	3	2
1525	212	25.5	148.0		7.05	2.06	11	18
1526	218	25.5	218.0		6 40	3.09	5	4
1527	221	74.5	98.0		7.70	4.43	18	21
1528	245	29.5	91.2		7.30	4.65	5	4
1531	222	118.5	160.0		5.10	2.38	5	2
1532	222A	234.0	220.0		5.50	2.99	5	2

Indian River—Concluded

Sample No.	Grove No.	Lbs./A Mn	Lbs./A Cu	Lbs./A Zn	pH	% O.M.	No. of Chlorosis Observations	
							New Leaves	Old Leaves
1533	232	111.8	562.0	104.0	5.35	5.25	6	9
1534	246	127.8	208.0		5.75	5.81	6	0
1583	251	83.2	56.8		5.15	2.68	5	0

Tavares

1529	350	48.0	160.0		5.05	1.39	0	3
1530	351	70.5	170 0		5.70	1.05	3	5
1584	301	159.5	80.0		5.78	.99	1	4
1585	302B	106.5	174.0		4.95	.95	4	8
1586	304	147.0	195.0	67.0	4.75	.99	0	0
1587	307	117.2	82.0		5.35	.95	0	1
1588	310	140.8	88.0		5.10	1.02	4	9
1589	312	48.0	62.0		5.05	1.66	0	5
1590	315	55.5	63.2		5.28	1.93	4	9
1591	320	83.2	62.0		5.78	1.79	0	9
1592	321	80 0	58.0		5.30	1.48	0	2
1593	324	266.0	160.0		6 45	1.16	0	1
1594	325	106.5	75.2		6.05	1.21	0	0
1595	327	53.2	35.2	46.0	5.82	.81	16	11
1596	330	74.5	88.0		5.62	1.32	2	1
1597	331	53.2	79.2		5.30	1.05	0	2
1598	333	197.0	165 0		5.72	1.56	1	15
1599	334	144.0	146.0		7.05	1.60	0	3
1600	337	111.8	177.2		5.48	2.99	0	5
1601	338	211.0	92.0		5.80	1.89	0	3
1602	339	66.0	91.2		4.85	.95	0	2
1603	344	80.0	68.8		5.20	2.49	0	2
1604	345	83.2	86.0		5.58	1.10	0	2
1605	346	288.0	140.0		5.45	1.67	5	6
1606	347	229.5	154.0		4.95	2.26	0	0
1607	349	147.0	178.0		5.20	.93	9	11
1608	352	225.0	258.0	120.0	5.35	.66	0	2
1609	353	154.5	98.0		5.40	1.77	0	3
1610	354	51.2	92.0		5.55	1.01	0	1
1611	355	55.5	108 8		5.20	1.50	0	5
1612	356	23.4	66.0		6.00	1.15	0	2
1613	357	256.0	32.0	24.0	6.52	1.77	0	3

West Coast

1465	401	161.0	253.0		5.30	2.24	8	6
1465	402	218.9	189.0		5.52	1.26	4	0
1467	403	78.4	56.8		4.95	2.34	10	10
1468	404	79.8	82.0		5.85	1.56	17	15
1469	406	118.9	123.2		5.80	1.10	6	4
1470	408	159.8	123.6		5.50	1.59	6	4
1471	409	13.1	36 4		5.88	2.79	5	0
1472	415	50.8	36.0	21.0	4.80	2.46	1	3
1473	417	107.2	88.0		5.15	1.57	13	3
1474	419	130.5	88.8		5.42	1.91	15	1
1475	420	95.9	70.0	28.0	4.65	2.69	7	1
1476	423	300.2	205.6	65.0	5.80	3.17	14	5

West Coast—Concluded

Sample No.	Grove No.	Lbs./A Mn	Lbs./A Cu	Lbs./A Zn	pH	% O.M.	No. of Chlorosis Observations	
							New Leaves	Old Leaves
1477	424	178.5	104.0		5.60	1.58	15	1
1478	430	177.0	212.8		5.20	1.58	11	11
1479	431	124.8	140.4		5.55	.86	4	4
1480	432	59.4	68.8		5.00	1.01	6	0
1481	433	145.0	102.0		5.30	1.83	0	0
1482	445	76.9	118.8		4.65	1.25	4	3
1483	446	207.5	60.0		5.82	1.28	8	6
1484	460	313.1	216.0		5.60	1.30	1	0
1485	461	118.8	79.2		6.00	.50	0	0
1486	475	146.5	176.4		4.85	2.90	29	20
1487	476	254.0	430.0	137.0	6.95	2.65	27	15
1488	477	82.6	56.8	39.0	5.85	1.11	7	6
1489	490	133.2	115.6		6.10	2.42	19	13
1490	491	213.5	127.2		5.35	1.69	39	36

Avon Park

1370	507	120.0	188.0		5.45	1.07	0	0
1371	515	78.0	212.0		5.25	2.08	1	0
1372	523	145.0	264.0		5.30	1.46	9	2
1373	541	131.0	144.0	63.0	5.80	1.21	8	0
1383	502	118.0	224.8		5.70	1.37	27	2
1384	503	48.0	134.0		4.90	1.08	7	0
1385	510	86.0	168.0		5.60	1.08	3	0
1386	513	50.0	84.8		5.90	.97	8	0
1387	514	178.0	153.6		6.15	1.03	1	0
1388	517	131.0	256.0		5.60	1.01	2	0
1389	518	124.0	224.4		5 30	1.03	13	0
1390	520	176.0	310.0		5.55	.88	2	0
1391	521	414.0	355.0	86.8	6.30	8.8	18	1
1392	522	226.0	266.0		6.60	1.17	0	2
1393	525	28.2	112.0		4.95	2.33	0	0
1394	527	154.0	144 0		4.95	4.8	1	0
1395	528	66.3	78.0		5.60	1.29	0	0
1396	531	23.9	82.0		5.50	2.90	2	0
1397	532	77.6	58.0		5.05	2.44	1	0
1398	535	142.5	42.0		5.80	2.90	14	0
1399	537	11.3	34.0	26.5	5.30	1.85	3	0
1400	539	63.4	84 8		5.10	1.50	9	1
1401	540	93.0	121.6	36.8	4.85	2.40	1	0
1402	542	91.6	246.0		5.75	.84	4	1
1403	543	124.0	243.0		5.35	1.19	0	0
1404	544	197.2	255.0		5.65	2.65	0	0
1491	509	207.5	124.0		5.05	.86	5	0

EFFECT OF SOIL TYPE AND FERTILIZER TREATMENT ON MINOR ELEMENT NUTRITION OF TUNG TREES

Matthew Drosdoff *

Tung trees are grown on a wide variety of soils in Florida ranging from the relatively heavy textured soils such as Red Bay sandy loam and related types in north Florida to the very sandy soils such as Lakeland sand and related types common in peninsular Florida. All these soils are relatively low in one or more minor elements and of necessity much attention has been given in tung research to minor-element nutrition problems.

ZINC

Soils on Which Deficiency Occurs

Zinc is the most widely needed and used of all the minor elements in tung fertilization. The lack of zinc caused considerable loss in many of the early tung orchards until the trouble was identified by Mowry and Camp (17) and corrective measures applied. They reported that zinc deficiency was found on a wide variety of soils, although their earlier studies had indicated that it was associated more with soils high in phosphatic materials.

Observations in recent years indicate that zinc fertilization is required on practically all soils in Florida for satisfactory tung production. On the heavier soil types in northwest Florida, such as those of the Ruston, Red Bay, Norfolk, Tifton and associated series, the zinc requirement is less than on the light-textured soils in peninsular Florida, such as those of the Lakeland and Arredondo series. Nevertheless, it is recommended that soil applications of at least 2 ounces of zinc sulfate per tree per year be applied to all tung plantings especially in the early years (7).

Zinc Available to Tung Trees as Indicated by Leaf Analysis

Leaf analysis has been helpful in determining the amount of zinc available to tung trees on various soils (8). Table 1 gives the zinc content and degree of deficiency symptoms of tung leaves from different-age trees on various soil types in relation to zinc fertilization. It should be noted that leaves from trees on all the soils have a very low zinc content, 10 to 15 PPM, where no zinc sulfate has been applied. Usually such leaves show severe deficiency symptoms. A 2- to 4-ounce soil application of zinc sulfate per tree per year ordinarily corrects the deficiency and increases the zinc content to 30 or more parts per million. However, with 2-year-old trees on Faceville soil, the 4-ounce application of zinc sulfate was not sufficient to correct the deficiency.

Fixation of Zinc

In the Gainesville tung area on some soils, especially those of the Gainesville, Arredondo, and Lakeland series, it has been difficult to cor-

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TABLE 1.—Zinc Content of Tung Leaves from Trees on Different Soils in Relation to Deficiency Symptoms and Zinc Fertilization.

Location	Age of Trees	Soil Type	Zinc Sulfate Applied per Tree	Leaf-Deficiency Symptoms	Zinc (PPM—Dry Matter Basis)
Gainesville, Fla.	1	Arredondo fine sandy loam	None	Severe	15
Gainesville, Fla.	1	Arredondo fine sandy loam	4 oz.	None	30
Alachua, Fla.	1	Gainesville fine sandy loam	None	Severe	14
LaCrosse, Fla.	1	Lakeland fine sand	None	Severe	12
LaCrosse, Fla.	2	Lakeland fine sand	2 oz./year	None	73
Reddick, Fla.	7	Arredondo loamy fine sand	None	Severe	11
Lloyd, Fla.	6	Red Bay fine sandy loam	None	Severe	10
Capps, Fla.	6	Red Bay fine sandy loam	2 oz./year	None	36
Milton, Fla.	12	Orangeburg loamy sand	None	Moderate	14
Milton, Fla.	12	Orangeburg loamy sand	1 lb./year for last 2 years	None	67
Lamont, Fla.	2	Faceville fine sandy loam	4 oz./year	Moderate	15
Monticello, Fla.	10	Ruston fine sandy loam	2 oz./year	None	42

rect zinc deficiency of young tung trees by soil applications of zinc sulfate. Ordinarily a 2-ounce soil application per tree is sufficient to control zinc deficiency on newly planted trees, but in some cases this does not give satisfactory control. For complete control in such cases it is necessary to spray the trees with a mixture of 8 pounds of zinc sulfate plus 8 pounds of hydrated lime in 100 gallons of water.

The ineffectiveness of soil applications of zinc sulfate to trees on many of the sandy soils of peninsular Florida has been attributed either to leaching from the soil especially during periods of high rainfall or to the fixation of zinc in a relatively insoluble form. Recent work by Shear (22) indicates that considerable zinc can be fixed by Lakeland fine sand in a form not available to tung trees. He applied 3 levels of zinc in a nutrient solution to trees growing in bottomless steel cylinders containing 2 kinds of medium, (1) pure quartz sand and (2) undisturbed Lakeland fine sand. The total amounts of zinc applied during the season were equivalent to 0.056, 0.225, and 2.25 ounces of zinc sulfate per tree for the low, intermediate and high levels of zinc, respectively. No zinc deficiency was apparent on any of the trees growing in quartz sand even at the low level of zinc applied. On the other hand, zinc-deficiency symptoms were severe on the soil-grown plants at both the low and the intermediate level of zinc supply. Leaf analyses showed zinc to be much higher in the leaves of the quartz-sand-grown plants. Undoubtedly leaching of nutrients was much greater from the quartz sand than from the soil, so that the lack of response to the lower levels of zinc applied to the Lakeland fine sand was probably due to fixation of the zinc by the soil in a relatively unavailable form.

In one area near Hague, Florida, zinc deficiency of young tung trees on Gainesville loamy fine sand has been especially difficult to control by soil applications of zinc sulfate. Apparently this soil has a high capacity for fixing zinc in an unavailable form. Dyal (10) extracted the clay from this soil and found a large amount of mica leptyls and some wavellite which may possibly account for its high zinc-fixing capacity. Earlier work at the Florida Experiment Station (15) had indicated the influence of clay and also organic matter in zinc fixation.

Effect of Applied Fertilizers on Zinc Uptake

There have been a number of reports on the effect of applied lime and phosphate on zinc uptake by plants (2, 21), but data on the effect of other elements are limited. In sand-culture work with tung, Shear *et al.* (23) found that increasing the levels of potassium, calcium, and magnesium decreased the zinc uptake by young tung trees as measured by leaf content of zinc. In a field experiment with bearing tung trees on Lakeland fine sand having a satisfactory zinc supply, Drosdoff *et al.* (9) found that increasing the levels of nitrogen, calcium, and magnesium decreased the zinc content of the leaves but increasing the level of potassium had little effect. In the field experiment the decreased zinc content of the foliage was associated with treatments which increased yield of fruit and undoubtedly growth. In the sand-culture experiment there was no relationship between increased growth and decreased zinc content of the leaves. Consequently, it is likely that different combinations of factors in the greenhouse and under field conditions caused the difference

in potassium response. In a controlled nutrient-culture experiment with young tung trees on Lakeland fine sand, Shear (22) found that increasing potassium levels decreased the zinc content of the leaves only at low levels of zinc supply. In a field experiment with citrus on a Lakeland soil at a low zinc level, Reuther and Smith (19) found that increasing the level of nitrogen and potassium decreased the zinc content of the foliage and increased the degree of zinc-deficiency symptoms.

There is evidence that under some conditions fertilization with nitrogen, potassium, calcium, and magnesium may have a pronounced effect on zinc nutrition. Probably a combination of factors is involved, depending on the zinc supply and the amount of the other elements added.

Zinc Deficiency in Old Cultivated Versus Newly Cleared Land

It has been generally believed that land cultivated over a long period is more likely to be deficient in zinc than newly cleared land. Experience with tung trees has shown that this is not necessarily so. Tung plantings on newly cleared land of the Arredondo, Lakeland, and Gainesville soil series have shown severe zinc-deficiency symptoms. On the other hand, under cultivation and certain other soil management practices, zinc deficiency can be minimized. Barnette *et al.* (1) found that permitting the land to lie fallow to volunteer weeds and grasses reduced materially the amount of zinc deficiency in the corn crop that followed. Subsequently, Rogers *et al.* (20) showed that the zinc content of weeds and grasses on those soils, Norfolk and Hernando fine sands, was much higher than that of planted Crotalaria. This illustrates the capacity of certain plants to absorb considerably more zinc than others from the same soil and is a factor to consider in managing soils deficient in zinc.

Zinc Deficiency in Relation to Age of Tree

The control of zinc deficiency is more of a problem with young trees than with older established ones. After the first two or three years of growth, small soil applications of about 2 ounces of zinc sulfate per tree per year are usually sufficient to prevent zinc deficiency on most soils, even on those where zinc deficiency was severe in the early years and difficult to correct. In other words, about the same amount of applied zinc sulfate and often less is needed for older trees in zinc-deficient soils. The reason for this is not clear. Either the tree roots in time get more zinc from the deeper soil horizons or their capacity to absorb zinc from the shallower horizons increases with age, or perhaps some other factor is operating.

COPPER

Soils on Which Deficiency Occurs

Copper deficiency of tung was diagnosed relatively recently (6) and has been observed and reported only on certain soils in peninsular Florida. These are sands and loamy fine sands of the following series: Ft. Meade, Arredondo, Gainesville, Blanton, and Lakeland. Only a few tung orchards on these soil types have shown copper-deficiency symptoms. Many factors are involved in the incidence of the symptoms. Probably the most important are the management and fertilizer practices used, the kind of trees planted, and the natural variation in the available copper within the soil type.

TABLE 2.—COPPER CONTENT OF TUNG LEAVES FROM TREES ON DIFFERENT SOILS IN RELATION TO DEFICIENCY SYMPTOMS AND COPPER FERTILIZATION.

Location	Age of Trees	Soil Type	Copper Sulfate Applied per Tree	Leaf-Deficiency Symptoms	Copper (PPM Dry Matter Basis)
Alachua, Fla.	1	Gainesville fine sandy loam	None	Severe	2.9
Alachua, Fla.	1	Gainesville fine sandy loam	1/6 oz. in solution	None	4.0
Alachua, Fla.	2	Ft. Meade loamy fine sand	None	Severe	2.8
Alachua, Fla.	2	Ft. Meade loamy fine sand	4 oz. second year	None	4.5
Alachua, Fla.	2	Arredondo loamy fine sand	½ oz./year	Severe	2.3
Alachua, Fla.	2	Arredondo loamy fine sand	3 oz./year	Slight	3.4
Morriston, Fla.	10	Ft. Meade loamy fine sand	None	Severe	2.5
Morriston, Fla.	10	Arredondo loamy fine sand	None	None	5.2
Lamont, Fla.	10	Ruston fine sandy loam	None	None	8.3
Monticello, Fla.	10	Faceville fine sandy loam	None	None	9.5
Cairo, Ga.	5	Red Bay fine sandy loam	None	None	6.4

A soil application of about one ounce of copper sulfate per tree is recommended for control of copper deficiency of newly planted tung trees on these soils. More than this amount applied at one time may burn the foliage. If necessary, a second application is made later in the season. As with zinc, soil applications of copper sulfate often will not prevent or correct copper deficiency especially during the first two or three years of growth. Undoubtedly the same mechanism is operating in copper fixation in these soils as with zinc fixation.

When satisfactory response is not obtained with soil applications of copper sulfate, complete control can be obtained by spraying with a copper-lime mixture of 8-8-100.

To date no copper deficiency of tung has been observed or reported on the finer textured soils of northern and northwestern Florida such as the Red Bay fine sandy loam and related or associated soil types.

Copper Available to Tung Trees as Indicated by Leaf Analysis

The copper contents of tung leaves from trees growing on different soil types reflect the amount of copper available in the different soils. Data given in Table 2 are adapted from a recent publication (8). These data illustrate the occurrence of severe copper deficiency associated with very low copper content of the leaves, less than 3 PPM, on soils of the Gainesville, Ft. Meade, and Arredondo series in peninsular Florida. Soil applications which corrected the deficiency increased the copper content of the leaves to 4.0 and 4.5 PPM, indicating the very small amount needed by the plant for correcting copper deficiency. Tung trees on soils of the Ruston, Faceville, and Red Bay series in north Florida and south Georgia have a leaf content of copper of over 6 PPM and show no evidence of copper-deficiency symptoms.

Effect of Applied Fertilizers on Copper Deficiency

It has been found with tung as with citrus that on soils low in copper, increasing the nitrogen applied accentuates copper deficiency (13). Physiological studies (11) have shown that copper deficiency is characterized in tung by the formation of abnormal amounts of complex nitrogen compounds at the expense of the carbohydrate reserves of the plant. The result is a net increase in the protein content of the copper-deficient plants over that of normal plants. Subsequent work by Gilbert (12) suggests that the nitrogen supply to the plant influences copper metabolism by inactivation of copper ions by protein ions. Regardless of the mechanism involved in the nitrogen-copper relationship, it is of practical importance in soil areas low in copper to supply a proper balance of copper and nitrogen in the fertilizer mixture.

There has been considerable attention given to the effect of phosphate in the soil or applied superphosphates on the availability of copper. Working with citrus on sandy soils, Jamison (14) found that only in the presence of great excesses of soil phosphates far beyond ordinary practical usage, is the solubility of copper affected in most soils in peninsular Florida. This would indicate that under ordinary commercial management and fertilizer practices, the availability of copper to trees on sandy soils is not adversely affected by the phosphate present in the soil.

Similar results have been obtained with tung trees (5). It was found that in a copper-deficient area, ½ pound of 20 percent superphosphate

applied to the soil around one-year-old tung trees did not increase the incidence of copper-deficiency symptoms in comparison with those trees to which no superphosphate was applied. Similar results were obtained with older trees.

In an experiment previously cited (13), leaf samples were collected from plots receiving different fertilizer treatments. The phosphorus content of the leaves showed no sginificant relation to either the copper content of the leaves or the degree of copper-deficiency symptoms. Assuming that the phosphorus content of the leaves is proportional to the phosphorus available in the soil, then the data from this experiment give further evidence that the application of phosphate to the soil has no adverse effect on the copper uptake by the tung tree.

MANGANESE

Soils on Which Deficiency Occurs

Manganese deficiency of tung has been observed and reported only on the sandy soils in peninsular Florida of the following series: Lakeland, Blanton, Arredondo. Ft. Meade, Hernando, Fellowship, and Gainesville. Undoubtedly it exists on these same soils on tung in other parts of the state. The deficiency symptoms were first described by Reuther and Dickey (18). They also made a survey of about 8,000 acres of tung plantings and reported the various soil types on which manganese deficiency, or "frenching," was found. No manganese deficiency has ever been found in orchards on the heavier soils of north Florida, such as those of the Red Bay, Ruston, and related series. Severe manganese-deficient bearing tung trees on Arredondo loamy fine sand required 2 pounds of manganese sulfate per tree per year to correct the trouble (4). In general, on that kind of soil when there is only a slight amount of manganese deficiency, soil applications of 2 to 4 ounces of manganese sulfate per tree per year is sufficient. Up to now, however, it has not been demonstrated that the correction of slight manganese-deficiency symptoms increases yield (16).

Manganese Available to Tung Trees as Indicated by Leaf Analysis

The manganese contents of tung leaves from trees growing on different soil types reflect the amount of manganese available in the different soils. Data given in Table 3 are adapted from a recent publication (8). The striking feature of these data is the wide range in the manganese content of the leaves depending on the soil type and treatment. The leaves from deficient trees have less than 40 PPM manganese and those from normal-appearing trees have up to almost 2,900 PPM. As to be expected, manganese is lowest in the leaves from trees on the sandy soils of peninsular Florida which have not been treated. Applications of manganese sulfate increase the manganese content of the leaves considerably. The heavier soils of northern Florida apparently have high contents of available manganese as indicated by the high manganese contents of the leaves from trees on these soils. Apparently tung trees can accumulate large amounts of manganese without showing any evidence of manganese toxicity or iron deficiency. The iron content of tung leaves is about the same in the low- and high-manganese soils. This would indicate that the iron-manganese ratio in tung has no special significance.

TABLE 3.—Manganese Content of Tung Leaves from Trees on Different Soils in Relation to Deficiency Symptoms and Manganese Fertilization.

Location	Age of Trees	Soil Type	Manganese Sulfate Applied per Tree	Leaf-Deficiency Symptoms	Manganese (PPM—Dry Matter Basis)
Gainesville, Fla.	18	Arredondo loamy fine sand	None	Moderate	30
Gainesville, Fla.	18	Arredondo loamy fine sand	1 lb. last 2 years	None	80
Reddick, Fla.	10	Arredondo loamy fine sand	None	Severe	25
Reddick, Fla.	10	Arredondo loamy fine sand	2 lbs. last 2 years	None	100
LaCrosse, Fla.	10	Leon fine sand	None	None	90
Morriston, Fla.	8	Lakeland fine sand	None	Slight	36
Alachua, Fla.	1	Gainesville loamy fine sand	2 oz.	None	113
Ocala, Fla.	1	Lakeland fine sand	2 oz.	None	402
Lamont, Fla.	10	Ruston fine sandy loam	None	None	1846
Capps, Fla.	8	Red Bay fine sandy loam	None	None	2884
Monticello, Fla.	10	Faceville fine sandy loam	None	None	572

IRON

Soils on Which Deficiency Occurs

Iron deficiency of tung was diagnosed and described by Dickey (3). He observed it in only limited areas on poorly drained soils like the Leon fine sand and Scranton loamy fine sand under both very acid and alkaline soil conditions. It is not of much economic importance as only a small acreage of commercial tung orchards now exists on those kinds of soil.

Iron Available to Tung Trees as Indicated by Leaf Analysis

The iron content of tung leaves on different soil types has a relatively narrow range, 35 to 92 PPM (8). This is rather surprising in view of the fact that the leaf samples cover a wide range of soil types, from Lakeland and Leon fine sands of very low total iron content to the Red Bay and Ruston fine sandy loams which have a relatively large amount of total iron, especially in the subsoil. The leaf analysis data, however, suggest that there is not so much difference in available iron in these soils as might be expected. Dr. John G. A. Fiskel, of the Florida Agricultural Experiment Station, has obtained similar results in some preliminary analyses for available iron in soils.[1] Dyal (10) found that the .3-micron clay extracted from Lakeland fine sand and Red Bay fine sandy loam subsoils had about the same content of total iron oxide as well as of free iron oxide. Though there was about 8 times as much clay in the Red Bay soil as in the Lakeland soil, the similarity in the iron content of the clay complex in the two soils may be a clue to the iron availability.

BORON AND MOLYBDENUM

Up to the present, boron and molybdenum deficiencies in commercial tung orchards have not been observed or reported. Soil applications of boron in several different experiments over the tung belt have not been beneficial. Preliminary data obtained in a boron and molybdenum leaf analysis survey from representative tung orchards do not indicate any need for supplementary fertilization with these elements.

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CHELATES IN THE SOIL

Ivan Stewart and C. D. Leonard *

Iron ethylenediaminetetraacetate (FeEDTA) is being used commercially as a source of iron for several crops in Florida and other places (6). This is the only known form of iron that is readily available to many plants when applied to the soil. Iron from FeEDTA is most efficient on neutral or acid soils, whereas much higher rates are required on calcareous soils. Studies are now in progress toward developing more effective methods of supplying iron to citrus trees growing on calcareous soils. One of the approaches being used is to study the properties of iron chelates in soils. In addition to the work with iron, soil studies are also being carried on to determine the availability of zinc chelates to citrus trees.

When iron, zinc and other metals are supplied as nutrients to plants they are generally applied as inorganic salts, usually as the sulfates. From these salts, metals are assumed to be adsorbed by plants as cations. However, when these metals are combined with a chelating agent, their chemical properties are changed. Surrounded by a complexing agent, the metal changes from a cation and becomes part of an anion. This change from a positive to a negative charge apparently causes the metals to be much more available to plants. However, the availability of any particular metal chelate depends to a great extent upon its stability in the soil from which it is absorbed by the plant.

Studies were made of the stability of various chelates by passing dilute solutions through cation and anion exchange columns (Table 1). Fifty milliliters of the chelate containing 10 ppm. iron was passed through columns of a cation exchange resin IR-120 and through an anion exchange resin IRA-400. The chelates were labeled with C^{14}EDTA, $Fe^{55,59}$ and Zn^{65}. Zinc was used at a concentration of 20 ppm. All of the FeEDTA passed through the cation resin without adsorption, but was completely adsorbed on the anion exchanger. However, with the iron chelate of N-hydroxyethylethylenediaminetriacetic acid (FeEDTA-OH) all of the $Fe^{55,59}$ was adsorbed on the IRA-400 and 76 percent on the IR-120. This suggests that (FeEDTA-OH) was not as stable as FeEDTA and that the iron was exchanged from the chelate to the cation exchange resin. The stability constant for FeEDTA-OH is difficult to determine, but the log K value is believed to be approximately 21 (1). Iron EDTA has a log K value of 25. The difference in stability may account for the breakdown of the FeEDTA-OH and not the FeEDTA on the IR-120 resin.

Iron EDTA-OH has been found to be a better source of iron than FeEDTA in calcareous soils (2, 3). Chaberek and Bersworth (1) believe that the outstanding value of FeEDTA-OH in calcareous soils is due to its resistance to hydrolysis and subsequent formation of ferric hydroxide, and not to its high log K value.

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TABLE 1.—ADSORPTION OF CHELATES ON EXCHANGE RESINS COLUMNS.

Chelate †	Resin	Adsorption Percent
Fe*EDTA	IR-120	0
FeEDTA*	IR-120	0
Fe*EDTA-OH	IR-120	76
Zn*EDTA	IR-120	85
ZnEDTA*	IR-120	39
Fe*EDTA	IRA-400	100
FeEDTA	IRA-400	100
Fe*EDTA-OH	IRA-400	100
Zn*EDTA	IRA-400	100

† The * designates the position of the chelate that was labeled. Fe*EDTA = $Fe^{55,59}$EDTA, FeEDTA* = C^{14}FeEDTA, Zn*EDTA = Zn^{65}EDTA, and ZnEDTA* = C^{14}ZnEDTA.

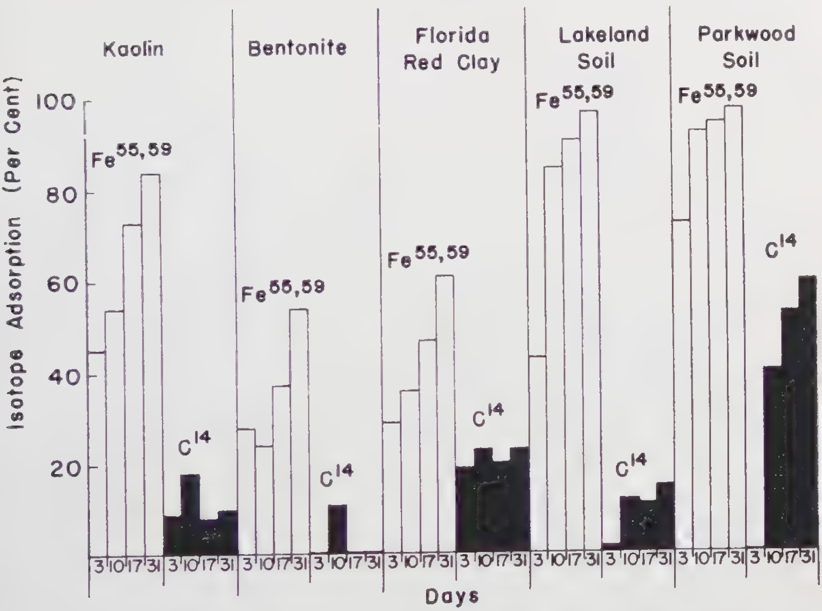
Studies with Zn^{65}EDTA and C^{14}ZnEDTA indicated that the zinc chelate was decomposed when passed through the cation ion exchange column. Eighty-five percent of the Zn^{65} was adsorbed by the IR-120 resin and 39 percent of the C^{14}. The nature of the adsorption of the chelating agent on the cation resin is not known.

Adsorption and exchange studies were made with iron chelates in Lakeland and Parkwood soils, bentonite, kaolin and Florida red clays. Lakeland fine sand was collected from a citrus grove that had been heavily limed and had a pH of 6.2. The Parkwood soil had a reaction of pH 8.0 and was taken from a citrus grove on Merritt Island. The procedure used for these studies was to put 100 grams of soil and 200 ml. of solution containing 10 ppm. Fe and an equivalent amount of chelating agent into a flask. In case of the kaolin, bentonite, and Florida red clay 10, 50, and 100 grams, respectively were used. All the treatments were triplicated. In part of the flasks the EDTA was labeled with C^{14} and in the others $Fe^{55,59}$ was used. The flasks were shaken for two hours and the supernatant was filtered at intervals. Counts were made with a Geiger counter on 2 ml. of the filtrate taken to dryness.

The results obtained are shown in Fig. 1. In addition to the isotope procedure for studying separately the properties of EDTA and iron, chemical analyses were made for iron in the filtrate, using o-phenanthroline. The iron in solution was assumed to be chelated because the solubility of the iron was found to depend upon the concentration of EDTA used in the extractant.

There was much more adsorption of $Fe^{55,59}$ than of the C^{14} (Fig. 1). The difference was more pronounced with the two soils than with the clays. However, when the chemical method for determination of iron (Table 2) was compared with the isotope procedure it was apparent that part of the chelated iron exchanged for iron in the soil. A similar exchange but to a lesser extent took place in the kaolin. There was little evidence of the iron-for-iron exchange in the bentonite or Florida red clay. The adsorption of iron by the Lakeland *grove* soil used in these studies was much higher than had been found previously in this laboratory for a Lakeland *virgin* soil.

Fig. 1 The isotope adsorption by clays and soils from $Fe^{55,59}$ EDTA and from C^{14} Fe EDTA



In addition to the iron-for-iron exchange in the soil other metals replaced some of the iron in the chelate. This is suggested by the data in Fig. 1. where in all instances more iron was adsorbed than chelating agent.

TABLE 2.—Percent Iron Adsorbed from FeEDTA by Clays and Soils as Determined by Chemical Methods 17 Days Following Shaking.

Adsorbing Material	Fe Adsorbed — Percent
Kaolin	46
Bentonite	44
Florida Red Clay	50
Lakeland Soil	73
Parkwood Soil	69

Adsorbtion of the chelating agent took place on all of the clays and soils used. Practically none of the EDTA was adsorbed by the bentonite and the highest amount was adsorbed by the Parkwood soil. The adsorbed complex may have been either FeEDTA or another chelate resulting from exchange of some metal in the soil for iron in the FeEDTA.

These studies demonstrate some of the dynamic properties of FeEDTA in the soil. For example the high rate of exchange of iron in the chelate

for other metals in the Lakeland soil probably explains the slow responses obtained in a few citrus groves following applications of FeEDTA. In these groves iron in the chelate is probably replaced by calcium in the soil. However following leaching to the acid subsoil, exchange again takes place forming FeEDTA where it is taken up by the tree roots. In some seasons considerable time may be required for the leaching of the chelate to the subsoil.

A comparison was made of five iron chelates in two samples of calcareous soil. The soil was Parkwood collected from a citrus grove in the Fort Pierce area. Soil 1 was taken from near chlorotic trees and Soil 2 from around nearby green trees. The pH's of the soils were approximately 8.0 and 7.6, respectively. Laboratory tests were made on these soils as previously described where iron was determined in the supernatant by the chemical procedure.

In these tests EDTA was more effective in keeping iron soluble than were any of the other chelating agents used (Table 3). The EDTA-OH and the N,N'dihydroxyethylethylenediaminediacetic acid (DEDD) were, however, almost as efficient as EDTA in keeping iron soluble. Practically all of the iron complexed by hydroxyethyliminodiacetic acid (HEIDA) and nitrilotriacetic acid (NTA) was precipitated immediately.

TABLE 3.—Absorption of Iron from Various Iron Chelates by Calcareous Soils.

Chelate *	Soil **	2 Hrs. Percent	24 Hrs. Percent	5 Days Percent	15 Days Percent	33 Days Percent
FeEDTA	1	31	31	63	59	71
	2	10	10	30	48	64
FeEDTA-OH	1	59	60	69	58	87
	2	31	29	53	64	69
FeDEDD	1	84	77	72	72	
	2	51	55	67	70	
FeHEIDA	1	100	96	96	100	
	2	88	96	96	100	
FeNTA	1	100	95	96	100	
	2	91	95	91	100	

* FeEDTA-iron ethylenediaminetetraacetate, FeEDTA-OH-iron—>N-hydroxyethylethylenediaminetriacetate, FeDEDD-iron N N[1] dihydroxyethylenediaminediacetate, FeHEIDA-iron hydroxyethyliminodiacetate, FeNTA-iron nitrolotriacetate.

** Parkwood soil. Soil 1 was taken near chlorotic trees and had a pH of 8.0. Soil 2 was taken within a few yards of soil 1 but was collected from an area where the trees were green. The pH was 7.6.

In the field FeEDTA-OH has been a much better source of iron for trees growing in Parkwood soil than has FeEDTA. Iron DEDD has been decidedly less available than either of the above two chelates while FeHEIDA and FeNTA have not been available to citrus trees in any type of soil. In using the above laboratory procedure to evaluate the capacity of chelating agents to keep iron soluble in a soil it is essential that the

iron and chelating agent be added in equivalent amounts. If an excess of chelating agent is added there will be an increase in the iron in solution. The increase will be proportional to the amount of the chelating agent added.

It would be highly desirable if metals other than iron could be applied to the soil as a chelate or as some other highly available form. One of the difficulties of supplying metal chelates other than iron is that rapid exchange of the metal in the chelate for the iron in the soil is believed to take place in many soils. Iron forms a much more stable chelate than the other metals. Perkins and Purvis (5) demonstrated this type of exchange in Collington soil using MnEDTA.

In the present studies, ZnEDTA was used in Lakeland sand. Zinc-iron exchange studies were made on a virgin Lakeland sand in the laboratory using a technique previously described. The extracting solution contained 20 ppm. Zn and an equivalent amount of EDTA. Measurements were made on the rate zinc which was removed from solution and the rate that iron came into solution. The latter procedure is believed to be a better means of measuring the rate of exchange. Exchange continued up to 13 days when the experiment was terminated.

Zinc is more effectively chelated by EDTA in dilute solutions with increasing pH (4). Conversely FeEDTA tends to hydrolyze with increasing pH. If these concepts hold true in the soil then ZnEDTA should be more effective as a source of zinc for plants in a limed soil than in a very acid soil. Actually, studies with Lakeland soil adjusted to various pH levels show this to be true. Citrus seedlings growing in the soil took up considerably more zinc from ZnEDTA at pHs 6 and 7 than pHs 4 and 5 (7). Studies are continuing in an effort to determine the optimum conditions for plant absorption of chelated zinc from the soil.

SUMMARY

Metal chelates were studied on ion exchange columns in clays and in soils. These studies were made with $Fe^{55,59}$, Zn^{65}, C^{14}EDTA and by chemical analysis.

Iron EDTA was stable on ion exchange columns of IR-120 and IRA-400. Iron EDTA-OH and ZnEDTA was unstable on the IR-120 column.

Studies with FeEDTA in soils and clays disclosed that exchange took place between iron in the soil and iron in the chelate. In addition there was exchange between iron in the chelate and other metals in the soil. Also there was some adsorption of the entire complex.

A comparison was made of the capacity of five chelating agents to hold iron in solution in two calcareous soils. Iron EDTA was the most effective followed by FeEDTA-OH and FeDEDD. Iron HEIDA and FeNTA were ineffective in keeping iron soluble in the soil.

Studies with ZnEDTA in Lakeland soil disclosed that exchange of the zinc in the chelate for iron in the soil was continuing after 13 days. The rate of exchange is believed to decrease with increasing pH of the soil.

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A PRELIMINARY SURVEY OF THE COBALT CONTENTS OF SOUTH FLORIDA FORAGES

ALBERT E. KRETSCHMER, JR., VICTOR A. LAZAR, and KENNETH C. BEESON *

A complete review of "salt sick" disease of cattle as it was found in Florida previous to 1931 was reported by Becker, Neal, and Shealy (3). It was not until 1937, however, that Neal and Ahmann (4) actually found that "salt sick" disease could be cured by addition of Co to the ration. A comprehensive survey of the literature pertaining to Co in soils, plants, and animals has been compiled by Beeson (1).

The nature of a majority of the sandy soils in south Florida is such that the total Co content would be expected to be low. Analyses for acid soluble Co in Florida soils substantiates this (5). Since no data are available for Co contents of Everglades organic soils or forages, a preliminary survey of forages growing on these and on sandy soils of the area was initiated. The preliminary results are presented here.

METHODS

Forage samples were taken by hand and soil samples usually were taken simultaneously. Plant material was dried at 70-75° C. and ground through a Wiley mill or Nylon slip-roll Pulverizer (6). The o-nitrosocresol procedure was used for the determination of Co (2). In order to permit a more valid comparison between the same plant varieties growing in different locations certain sampling techniques were arbitrarily established. The plant portions included in the analyses were as follows: white clover—leaves plus petioles; Para grass and carib grass—meristem down to next to uppermost node, including leaves and stems; pangola grass—leaves plus meristems; St. Augustine grass—leaf blades; hubam clover, alfalfa, fescue grass, ryegrass, and oat plant—above ground portion from 3 to 4 inches above soil surface; Bermuda grass—leaves plus stems. Some of the samples collected in this manner would differ from that portion grazed by the animals. For instance, the intake of St. Augustine grass would include varying quantities of stem portions depending on the condition of the pasture. The same effect would be applicable to carib grass, Para grass and pangola grass. Thus the cobalt intake of the animal might vary depending on the proportion of leaves and stems in the plant grazed.

Soil pH, loss on ignition, and moisture equivalent were determined by conventional procedures.

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TABLE 1.—The Cobalt Contents of Various Winter Forages Growing on Everglades Peaty Muck Soil, Moisture-Free Basis.

Variety	Cobalt Content
	ppm.
1. Hubam clover	0.130
2. Louisiana white clover	0.090
3. Alfalfa	0.083
4. Ryegrass	0.067
5. Fescue grass (Ky. 31)	0.060
L.S.D. .05	0.024
L.S.D. .01	0.035

TABLE 2.—The Average Cobalt Contents of Five Different Forages as Affected by the Application of Six Ounces of Cobalt Sulfate per Acre in a Mixed Fertilizer, Moisture-Free Basis.

Treatment	Cobalt Content
	ppm.
1. Plus Cobalt	0.09
2. No Cobalt	0.06
3. Plus Cobalt	0.05
4. No Cobalt	0.05
L.S.D. .05	0.02

TABLE 3.—Cobalt Contents of Various Forages as Affected by Cobalt Treatment Applied by Plane, Moisture-Free Basis.

Forage	Treatment	Cobalt Content ppm.
1. Roselawn St. Augustine grass	+Co	0.16
2. White clover	+Co	0.13
3. Para grass	+Co	0.19
4. Roselawn St. Augustine grass	+Co	0.18
5. Para grass	—Co	0.06
6. Bermuda grass	—Co	0.08
7. Roselawn St. Augustine grass	—Co	0.09
8. Roselawn St. Augustine grass	—Co	0.05

RESULTS

Samples were collected of various winter forages growing in replicated plots on Everglades peaty muck soil that had been under cultivation for about thirty years. Results of the cobalt analysis are included in Table 1. Hubam clover absorbed more Co per unit of dry weight than the other varieties while no differences existed between the contents of fescue grass, alfalfa, and ryegrass.

In another test several forages were collected from four similarly treated fields, two of which in addition had received Co in a mixed fertilizer at a rate of six ounces of twenty-one percent cobalt sulfate per acre. Cobalt treatment was made about four months prior to sampling. There were no statistical differences between the Co contents of hubam clover (0.08 ppm), ryegrass (0.07 ppm), oat plant (0.05 ppm), alfalfa (0.07 ppm), and Louisiana white clover (0.06 ppm). Cobalt contents of these forages were averaged for the four fields and are reported in Table 2. Although some increased absorption of Co per unit of dry weight was noted for one field of the Co treated forages the contents were still below 0.10 ppm Co.

Analyses of forages taken from one ranch, part of which had been treated by airplane application with six ounces of cobalt sulfate per acre, are reported in Table 3. Samples were taken about one month after cobalt treatment. Applications of Co by this method, at the rate of six ounces per acre, were much more effective in increasing Co contents of forage than ground applications. Treated forages contained between 0.10 and 0.20 ppm Co. It is highly probable, of course, that some of the cobalt found was a result of surface contamination of the plant.

In a test to determine the effect of different stages of growth of permanent pasture grasses on Co contents, twelve samples were taken from twelve different established pastures on successive dates. All of the grasses were growing on Everglades peaty muck soil. Eight samples of Roselawn St. Augustine grass, and two each of carib grass and Para grass were included in the test. Results of the Co analyses are reported in Table 4. The mean Co contents were very low for both sampling dates but it appears from these meager data that during periods of rapid grass growth, such as the May sampling date, the Co contents of grasses would be expected to be lower than during periods of slower growth. There were no significant differences in Co contents between varieties.

Cobalt contents of forage samples collected throughout the Everglades area (organic soils) and those from sand soil areas in three counties were considered separately. No significant correlations were found between the effects of per cent moisture equivalent and pH (sandy soils), and loss on ignition and pH (organic soils) on the Co contents of these forages. Cobalt contents of the twenty white clover samples (some of which may have been treated with Co) collected from sandy soils ranged from 0.04 to 0.32 ppm and averaged 0.10 ppm. Three of these samples contained 0.04 ppm or less, and six contained more than 0.07 ppm Co. The sixty-three Co analyses of forages growing on organic soils, taken from permanent pastures, resulted in some rather important findings. Values ranged from 0.01 to 0.26, and averaged 0.06 ppm Co. Of these samples, seventeen contained 0.04 ppm or less, and only fifteen contained greater than 0.07

ppm Co. Using a value of 0.07 ppm Co in the forage as deficient with respect to grazing animals, more than seventy-five per cent of the organic soils produce forages that are deficient in Co.

TABLE 4.—The Effect of Successive Dates of Sampling on the Cobalt Content of Various Grasses Grown on Everglades Peaty Muck Soil, Moisture-Free Basis.

Plant Variety	Cobalt Content — ppm.	
	2/17/54	5/10/54
1. Roselawn St. Augustine grass *	0.04	0.05
2. Roselawn St. Augustine grass *	0.06	0.03
3. Roselawn St. Augustine grass *	0.03	0.04
4. Roselawn St. Augustine grass *	0.07	0.05
5. Roselawn St. Augustine grass *	0.08	0 02
6. Roselawn St. Augustine grass *	0.06	0.05
7. Roselawn St. Augustine grass *	0.06	0.03
8. Roselawn St. Augustine grass *	0.05	0.02
9. Carib grass **	0.08	0.04
10. Carib grass **	0.07	0 05
11. Para grass **	0 08	0.06
12. Para grass **	0.07	0.03
Mean†	0 063	0.039

* Leaf blades only.

** Meristem, leaf blades and stems down to next to uppermost nodes.

† Difference between means is highly significant ($L.S.D._{.01}$ — 0.018).

DISCUSSION

Fertilizing sandy soils with Co is probably not economical. A pound of cobalt in a mineral mix would supply as a feed supplement adequate Co for a thousand head of cattle annually, assuming minimum consumption of one milligram of Co daily per head. This quantity of Co would cost about five dollars. At a rate of six ounces of twenty-one percent cobalt sulfate per acre applied to pasture, about thirteen acres could be fertilized at the same cost. Since it is known that Co is leached from sandy soils, soil applications probably would have to be made every two or three years (1). Even if one animal were grazed per acre less than fifty animals could be adequately supplied with Co at a cost of five dollars.

A slightly different situation occurs in the case of the organic soils of the Everglades area. The preliminary survey has shown that by far the greater majority of samples contained inadequate amounts of Co. Mineral mixtures used in this area appear, in some cases, to be rather unpalatable. Not only do some animals consume the mineral infrequently, if at all, but it is not uncommon to find unthrifty individual animals in a herd of thrifty cattle all having access to the same nutrients. Symptoms in these affected cattle appear to be of nutritional nature. It is quite possible that inadequate intake of Co is a contributing factor. More often than not this condition will affect cows and calves. Under such conditions the most practical method for definitely insuring against Co deficiency

is by supplying Co through the forage. There would be little leaching of Co from the organic soils but the longevity of effectiveness as well as the best application methods are not known. It was indicated above that aerial application of Co was a better method than soil application but the minimum increase in cost per acre by plane application would be about fifty cents. Since two or three animals per acre are grazed on these pastures, a pound of cobalt (at a rate of six ounces of twenty-one percent cobalt sulfate per acre), assuming a period of effectiveness of five years, would supply adequate Co through the forage for about one hundred seventy animals. Animals grazing on pastures at the Everglades Experiment Station have been found to consume slightly less than twenty pounds of mineral mix annually per animal.[1] Normally the mineral mix used in this area contains 0.03 percent Co. Twenty pounds, therefore, would contain about twenty-seven hundred milligrams. At this rate of consumption, five dollars worth of cobalt would feed about one hundred and seventy animals annually. The price differential is small in this instance, between feeding the animals Co through the mineral or through the forage.

At the present time more tests are needed to determine the rates and effectiveness of Co applications on the absorption of Co by the plant.

SUMMARY

A preliminary survey was made of the Co contents of forages growing on the organic and sandy soils of south Florida.

1. In a small field test on Everglades peaty muck soil, hubam clover was found to absorb more Co per unit of dry weight than white clover, fescue grass, alfalfa, and ryegrass.

2. Soil applications of twenty-one percent cobalt sulfate at a rate of six ounces per acre were not as effective in increasing the Co content of forages as were aerial applications at the same rate. Cobalt contents of grasses treated with Co by plane applications ranged between 0.10 and 0.20 ppm.

3. In a field test, including twelve samples, the Co contents were significantly higher in early spring than in late spring.

4. The Co content of white clover growing on sandy soils ranged from 0.04 to 0.32 ppm, and averaged 0.10 ppm.

5. The Co contents of forages growing on the organic soils ranged from 0.01 to 0.26, and averaged 0.06 ppm Co. Of these sixty-three samples, seventeen contained 0.04 ppm or less while only fifteen contained greater than 0.07 ppm. More than seventy-five percent of the samples contained inadequate amounts of Co for optimum animal health.

6. The economical feasibility of fertilizing with Co on sandy and organic soils was discussed.

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ANIMAL REQUIREMENTS AND PASTURE SOURCES OF TRACE ELEMENTS IN FLORIDA

G. K. Davis *

While a number of other trace elements have been demonstrated to be required by animals only a few must be supplied by supplements to feed. In Florida the elements with which we are principally concerned are cobalt, copper, manganese and iron. Copper cannot be considered without a consideration of molybdenum.

Cobalt. Extensive work both here and at other experiment stations has demonstrated that cobalt as a part of the vitamin B_{12} molecule is required by many species, but the requirements for cattle per kilo of live weight are much higher than those of other species with the possible exception of sheep. A level of .05 ppm. of cobalt in the dry matter appears to be the level below which cobalt deficiency may be expected to develop. Above .07 ppm. in the dry matter cobalt deficiency has not been observed. Cobalt deficiency is not a problem if .07 ppm. or more is included in the daily feed. Between .04 and .07 ppm. a borderline deficiency of cobalt may develop which while not expressing itself in frank clinical symptoms may, nevertheless, be limiting in the production of the animals.

Expressed in a different way, an animal weighing a thousand pounds requires one milligram of cobalt per day. However, our radioactive studies using radioactive cobalt have indicated that approximately .05 mg. of the daily intake is actually absorbed by the animal and may therefore be considered as a minimum requirement of the animal for good nutrition.

Since the requirement of cobalt is actually a requirement for vitamin B_{12} and it has been demonstrated that the cow has a very high level of vitamin B_{12} requirement, some attempt has been made to determine the vitamin B_{12} requirement for cattle. The retention of vitamin B_{12} and its utilization are quite poorly understood. It has been shown that a level of 350 gamma of B_{12} per 100 pounds per day is adequate for cattle and this may be shown to be equivalent to .14 mg. cobalt per 1000 pound animal. However, the requirement for vitamin B_{12} has not definitely been determined. It may well be that actual requirement is on the order of 125 gamma per 100 pounds of live weight. Since minimum levels are rarely optimum levels it is probably well to assume that the animal should have in its feed in the neighborhood of from .5 to 1 mg. of cobalt per 1000 pounds of live weight daily which will adequately take care of the vitamin B_{12} synthesis requirements of the ruminant.

Since we are always interested in supplying feed requirements through pastures it is of interest to note the cobalt content of the different pasture forages. Our experience has indicated that actual values of cobalt on

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the dry matter basis for different forages may range from as low as .001 ppm. to more than 4 ppm. Since .001 ppm. is probably near the limit of sensitivity of our methods, it may be that lower values do occur. Since these values have been obtained on forage which appears to be normal it seems pertinent to remark, that no relation has been shown to exist between pasture growth and development and the cobalt content of the pasture.

It has been customary to assume that legumes such as alfalfa and the clovers would supply adequate amounts of cobalt if they were able to grow. However, analytical values of .02 to .03 ppm. occur, and clovers and alfalfa cannot be depended upon blindly to supply adequate cobalt. This further demonstrates that there is no relationship between the cobalt content of plants and their growth. Cobalt values are dependent upon the cobalt content of the soil. In grasses the values which have been obtained have been very much lower than those for legumes, although with fertilization these values may be quite high. Most of our analyses have indicated values of less than 1 ppm. and perhaps a majority of grasses from Florida have analyzed less than .05 ppm. unless subjected to cobalt fertilization.

It is probably fair to say that unless some cobalt is applied as fertilizer, grasses on sandy soil may be expected to be too low in cobalt to adequately meet the requirements of cattle and that some supplementary source is necessary to maintain cattle in good nutrition.

Copper. Copper requirement of cattle in Florida has been difficult to determine unless the presence or absence of molybdenum has been ascertained.

In many of our sandy land pastures a level of 5 ppm. copper in the forage has apparently been adequate and the animals appear to be normal. On the other hand with the presence of as little as 1 ppm. of molybdenum the values of 5 ppm. have been inadequate and the development of copper deficiency symptoms have been observed. Levels of molybdenum of 2 to 3 ppm. have necessitated an intake of at least 10 ppm. of copper in the dry matter and levels of 50 ppm. of copper have been necessary to counteract levels of molybdenum as high as 150 ppm. Levels above 150 ppm. have not been adequately controlled by administration of copper and it may be assumed that wherever pastures are consistently above this level it will be necessary to take steps to lower the molybdenum content of the forage by controlling the pH of the soil.

In terms of copper sulfate, $CuSO_4 \cdot 5H_2O$, it has been rather well demstrated that the level of 0.5 gram of copper sulfate per day for a 1000 pound animal from all feed sources is an adequate and satisfactory intake. This appears to be the case even where low levels of molybdenum are present in the feed. In supplying the copper to the animals, levels up to 15 ppm. of the dry matter of pasture forage may be supplied readily through the application of copper fertilizers to the pastures as this appears to be a level readily achieved by such a practice.

Forage analyses from peat soils and from sandy soils have indicated a range of from 2.2 ppm. to 24.2 ppm. where copper has not and where copper has been applied. Apparently application of copper fertilizers to the peat soils may cause a precipitous rise in copper content of forage for a short period of time, but with continued growth the copper may level

out in its value to somewhere between 10 and 15 ppm. Our experience has indicated that even with a heavy copper fertilization on peat soil equilibrium values of 9 - 15 ppm. in the dry matter are average. On sandy land areas the normal copper value would appear to be somewhere between 5 and 10 ppm. of the dry matter with an average somewhere around 8 ppm. This would appear to be adequate and readily achieved with a unit of copper applied in the fertilizer. With continued pasturing after a single application on acid sandy soil the copper level tends to fall in the forage and most of our sandy land will produce a copper deficiency syndrome of improper calcification within 4 to 5 years after copper application of 10 lbs. of $CuSO_4 \cdot 5H_2O$ per acre if the fertilizer program is not continued. and copper is not supplied as a supplement.

Although molybdenum has been shown to be a part of intestinal xanthine oxidase. the level of molybdenum required by animals has not yet been determined. and certainly is very. very low. On the other hand forage analyses of samples from many parts of Florida have indicated a range of from less than 1 ppm. to over 300 ppm. of molybdenum.

The pH of the soil is a factor in the molybdenum content of forage, the more alkaline the soil the higher the molybdenum may be in the forage. Since on the peat soils it may be impossible to maintain a level of copper in the forage adequate to meet the requirements of cattle, it is necessary to supplement the pasture copper through mineral mixtures or supplementary feed containing copper.

Manganese. Since the level of manganese in the forage ordinarily required by the cattle is assumed to be 15 ppm. on the basis of experimental work in several different states, it has not been customary to include manganese as one of the trace elements required by cattle in this state.

This has been on the assumption that in order to obtain good forage growth, it would be necessary to have at least 15 ppm. of manganese in the forage. It has been observed that many pastures analyze from 50 to 100 ppm. of manganese in the dry matter. We have usually considered manganese to be adequately supplied under known circumstances in Florida.

During the past 2 years, however, it has been observed that manganese levels may drop below 15 ppm. in some pastures, particularly on peat soils. This has suggested the possibility of a manganese deficiency although demonstrated symptoms still remain to be identified. Poor performance has occurred in some of these areas.

Further. work in the Nutrition Laboratory has demonstrated that possibly molybdenum may interfere with proper manganese utilization. Under these circumstances some part of the dietary manganese may have to be included in the supplementary mineral mixture or in terms of stepped up fertilization. Since the use of a unit of manganese sulfate in the fertilizer program usually results in a manganese level of from 30 to 70 ppm. in the forage of the dry matter basis this would seem to be the logical way of supplying manganese to the cattle. However, if this is not possible then inclusion of manganese in the level of ration at a level of .01% may be a logical procedure. This is rather a matter of insurance than in response to a definitely demonstrated need at the present time.

IRON. Although the early work in Florida indicated that iron may be a deficient element in some Florida forage it has been difficult to demonstrate an iron deficiency in cattle unless the animals were subjected to rather heavy parasite loads, either internal and external or both on low iron, sandy soil. A level of 100 ppm. of iron in the forage is certainly adequate and may be far in excess of requirements for mature animals. A level of 0.5 gram of iron per day is satisfactory for growing cattle weighing from 300 to 400 pounds and for mature animals will supply far more than the necessary replacement needs if hemorrhage or loss of blood due to parasites is not a problem.

On the other hand, because many of our animals are subjected to heavy parasite loads and loss of blood due to parasitism, inclusion of iron seems to be a logical procedure and mineral mixtures containing iron are certainly justified under our Florida conditions. Because of the difficulty of ascertaining an iron requirement it does not seem possible to place an actual value on the needs of cattle and consequently, the aim would seem to be to supply a surplus so that deficiency will not become a serious problem.

THE INFLUENCE OF MICRONUTRIENTS AND SULFUR ON THE YIELDS OF CERTAIN CROPS

Henry C. Harris, Roger W. Bledsoe, and Fred Clark*

INTRODUCTION

A large number of field and greenhouse experiments have been conducted by the authors to determine the effect on the growth of crops of the micronutrients [1] when applied to the soil. Copper, zinc and manganese sulfates are frequently utilized in such experiments, and it is possible that the effect of an application of these might be due to the sulfate. The writers found that the small amount of sulfur in a starter solution which was applied to cotton seed at planting time (unpublished results) was sufficient to keep the plants green for about a month until fertilizer was applied as a sidedressing. When sulfur was not applied, the plants developed a yellow color and became retarded in growth within two weeks after they came up (10). Thus it is evident that the sulfate part of these micronutrient compounds could be important. For that reason an effort has been made in most of these experiments to differentiate the effect of the micronutrients from that of sulfur. The results for tobacco are being prepared for another publication, but those for other field crops are presented in this paper.

REVIEW OF LITERATURE

The literature dealing with the effect of micronutrients on the growth of crops is voluminous and has been thoroughly reviewed (5). Possibly it should be mentioned that copper (7, 8 and 9) and zinc (1 and 2) have increased the yields of crops on soil similar to the soil in some of the experiments reported in this publication. An extensive review (6) of the influence of sulfur in plant nutrition has been made and nothing will be added except to say that in Florida several workers (4, 10 and 11) have found that sulfur applied to the soil is important for good crop production.

EXPERIMENTAL

The experiments reported in this publication varied in complexity with time, land available, and facilities to do the work. Their nature, particularly those at the greenhouse, will have to be given in the respective experiments. However, some information, applying mainly to the field tests, will be given in this section.

The field experiments were all conducted on Arredondo loamy fine sand, which is a soil derived from phosphatic limestone. It had a pH value of 5.7 and a total base exchange capacity of 3.7 milliequivalents per 100 grams of soil. The exchangeable cations in this soil in milligrams

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[1] The term micronutrient is used in this publication in the same sense as minor elements in much of the literature dealing with soils.

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per 100 grams were 6.4, 15.4 and 1.6 for potassium, calcium and magnesium, respectively.[2]

The land had previously been in corn and other field crops with uniform fertilization. Micronutrients had not been applied intentionally, except zinc. After the discovery of zinc deficiency for corn in this state (1 and 2), zinc sulfate was applied occasionally at the rate of about 15 pounds per acre in the corn fertilizer. Low analysis superphosphate had been used in the fertilizer mixture and ammonium sulfate was commonly used as a source of nitrogen. It therefore appears that a supply of sulfur had been applied to this soil in previous fertilization.

The chemicals used in the formation of the fertilizer treatments were reagent grade, except where the name indicates a commercial product or where otherwise stated. Certain chemicals had to be substituted for others in some treatments. For example, if it were desired to have no sulfur, an equivalent amount of calcium lactate and magnesium acetate could be substituted for calcium sulfate and magnesium sulfate, respectively. Thus, the number of chemicals utilized and the complexity of treatments were larger than occur in many tests.

COWPEAS AND OATS

Residual Effects of Previous Micronutrient Treatments on the Yield of Cowpeas and Oats

In the fall of 1946, two test fields were seeded to oats to determine the effect of micronutients on yields. One of the tests was a 2^5 factorial experiment duplicated with the fourth order interaction confounded with blocks, as described by Yates (13). The variables in this test were the micronutrients. A basic, uniform fertilizer was applied to all plots, and treatments are listed in Table 1. Plots were 3 x 20 feet or 1/726 acre, with two rows of oats 18 inches apart planted in each plot. The proper amount of the micronutrients was mixed with the basic fertilizer and put in the furrow under the oats before seeding. Two rows of oats without fertilizer were planted between plots as borders.

The other test involved micronutrients, seed treatment, high nitrogen, and other variations. These treatments (listed in Table 2) were randomized in four blocks. The plot size, manner of fertilizer application, and seeding were the same as in the factorial test.

The oats in both tests were harvested May 5 and 6, 1947, the results of which are given in a previous publication (7 and 8).

Brabham cowpeas were planted in each of the tests on June 12, 1947. They were seeded in the same row position as the oats and retreated in the same manner with the basic fertilizer, but without the addition of micronutrients. They were inoculated with the proper legume organism before seeding, and hay yields were obtained on September 5 and 6, 1947.

After the cowpeas had been harvested, the soil was prepared and seeded to oats again December 5, 1947. The design and row arrangement for the factorial and randomized block tests were kept as originally, except Floralee oats were planted in one-half of each plot and Florida 167 oats in the other half. Again the proper basic fertilizer and micronutrient

[2] Values obtained through the courtesy of Dr. Nathan Gammon, Florida Agricultural Experiment Station.

treatment (indicated in Tables 1 and 2) was placed in the furrow under the oats before seeding in the manner already explained.

TABLE 1.—EFFECT OF PREVIOUS MICRONUTRIENT TREATMENT IN A FACTORIAL EXPERIMENT ON MEAN DRY YIELD OF COWPEAS AND TWO VARIETIES OF OATS.

Original Oat Treatment (For Cowpeas and Second Crop Oats See Notes)	Yield Cowpea † Hay Following Original Oats Lbs. per Acre	Yield Oats ‡ Following Cowpeas Bu. per Acre	
		Floralee	Florida 167
1. Fertilizer only*	2,857	1.8	1.6
2. Cu**	3,761	14.3	17.3
3. B	2,516	0.0	1.4
4. Cu and B	3,920	21.1	20.4
5. Mn	3,129	0.2	3.0
6. Cu and Mn	4,051	18.1	18.1
7. B and Mn	2,588	4.1	4.1
8. Cu, B and Mn	4,211	12.9	12.0
9. Zn	3,467	0.2	1.8
10. Cu and Zn	3,681	18.4	23.2
11. B and Zn	1,986	0.9	3.2
12. Cu, B and Zn	3,597	16.1	23.4
13. Mn and Zn	2,135	0.0	5.0
14. Cu, Mn and Zn	2,980	17.0	17.3
15. B, Mn and Zn	2,614	0.0	2.3
16. Cu, B, Mn and Zn	3,445	17.3	25.6
17. Mo	2,211	0.2	3.2
18. Cu and Mo	3,002	15.7	15.0
19. B and Mo	2,196	0.0	0.7
20. Cu, B and Mo	3,645	23.8	15.0
21. Mn and Mo	1,946	0.2	2.5
22. Cu, Mn and Mo	3,808	18.8	21.8
23. B, Mn and Mo	2,795	0.0	3.4
24. Cu, B, Mn and Mo	4,447	15.9	16.3
25. Zn and Mo	2,171	0.2	1.6
26. Cu, Zn and Mo	4,160	24.3	16.8
27. B, Zn and Mo	2,813	0.2	0.5
28. Cu, B, Zn and Mo	3,866	16.3	22.0
29. Mn, Zn and Mo	1,960	0.0	5.0
30. Cu, Mn, Zn and Mo	3,339	16.3	21.8
31. B, Mn, Zn and Mo	1,978	0.7	3.4
32. Cu, B, Mn, Zn and Mo	3,779	21.6	21.8
Average without Cu	2,461	0.6	2.7
Average with Cu	3,732	18.0	19.3

Difference due to copper in all cases highly significant statistically.
Other differences not significant, except Zn increased Florida 167 oats.

* An 0-12-12 at 500 lbs. per acre made from treble superphosphate (48% and potassium sulfate was applied to all plots. Magnesium chloride at the rate of 64 lbs. per acre and calcium sulfate (98% $CaSO_4.2H_2O$) at the rate of 93 lbs. were added to the fertilizer. Commercial sodium nitrate was applied as a topdressing at 150 lbs. per acre.

** The micronutrients were applied at the following rates in lbs. per acre: copper chloride, 10; boric acid, 2; manganese chloride, 10; zinc chloride, 10; and molybdic acid, 0.5.

† Cowpeas received 350 lbs. per acre of the above described fertilizer. Nitrate of soda and the micronutrients were not applied to this crop.

‡ The second crop of oats was treated again the same as originally.

The Florida 167 oats were harvested April 22, 1948 and the Floralee oats on May 7, 1948.

There was no noticeable difference in the appearance of the growing cowpeas except in the plots where molybdenum had been applied. The plants on these plots were a darker green color and seemed to be larger early in the growing period. About six weeks after germination, this difference began to disappear and at harvest time there was no difference in the appearance of the plants on any of the plots.

TABLE 2.—Effect of Previous Treatment in a Randomized Block Experiment on Mean Dry Yield of Cowpeas and Two Varieties of Oats.

Original Oat Treatment (For Cowpeas and Second Crop Oats See Notes)	Yield Cowpea‡ Hay Following Original Oats Lbs. per Acre	Yield Oats§ Following Cowpeas Bu. per Acre	
		Floralee	Florida 167
1. No treatment	1,532	0.2	0.9
2. Fertilizer*	2,033	0.5	1.4
3. Fertilizer + seed treatment (New Improved Ceresan)	2,207	0.5	0.9
4. Fertilizer + seed treatment + micronutrients**	3,652	15.0	21.3
5. Fertilizer + micronutrients	3,913	16.8	20.0
6. Fertilizer + high nitrogen†	2,098	0.0	0.5
7. Fertilizer + high nitrogen + seed treatment	1,771	0.9	0.9
8. Fertilizer + high nitrogen + seed treatment + micronutrients	3,492	21.3	22.7
L.S.D. at the 5% level	666	4.2	5.6
L.S.D. at the 1% level	892	5.7	7.1

* Same as for oats in Table 1.

** All five micronutrients at the rates indicated in Table 1.

† High nitrogen is 300 lbs. per acre of commercial sodium nitrate applied as a topdressing as compared to 150 with the regular fertilizer.

‡ Fertilizer on cowpeas same as in Table 1. Micronutrients were not applied to cowpeas.

§ Second crop of oats were treated again the same as originally.

Oats grown without an application of copper exhibited abnormal growth characteristics which have been described in a previous paper (7). With the exception of copper, other treatments had no noticeable effect on the appearance of the growing plants.

Yields are given in Tables 1 and 2. In the factorial test (Table 1), copper applied to the previous crop of oats increased the yield of cowpeas an average of about 52 per cent. The other micronutrients had no significant effect. In the randomized block experiment (Table 2) the five micronutrients applied to the previous crop of oats had a pronounced effect on the yield of cowpeas. Since the soil was the same in both tests and copper in the factorial experiment was the effective nutrient, the indications are that the copper in the micronutrient mixture was responsible for the increase in yield.

In the factorial experiment (Table 1), copper materially increased the yield of grain of both oat varieties. Other micronutrients had no large effect. In the case of the randomized block experiment (Table 2), no treatment—including fertilizer—had any appreciable effect on grain yield without the presence of the five micronutrients. In view of the other test, the effect of the addition of micronutrients was due to the copper in the mixture.

The yield of oat straw was affected similarly by applications of copper, but those results will not be presented.

Comparison of Different Ways of Applying Copper to Oats

Florida 167 variety of oats was seeded in field plots 6 x 10 feet on December 1, 1948. The treatments listed in Table 3 were randomized in five blocks and applied in the manner indicated in the table. It should be pointed out that the copper chloride on the oat seed was dissolved in water, sprinkled on the seed, the seed mixed, and dried just before planting. The spray, consisting of 2.5 grams of copper chloride in one liter of water, was applied as a fine mist on the foliage of the oats February 9, 1949.

TABLE 3.—Effect of Copper and Sulfur on the Mean Yield of Dry Forage in Pounds per Acre for Florida 167 Variety of Oats.

Treatment	Yield Pounds per Acre
1. Fertilizer* and four micronutrients**	125
2. Fertilizer and four micronutrients plus 120 pounds per acre flowers of sulfur mixed in top 4 inches of soil before seeding	176
3. Fertilizer and four micronutrients plus 0.18 pounds per acre of copper chloride in water on seed of oats	205
4. Fertilizer and four micronutrients plus 10 pounds per acre copper chloride in fertilizer	243
5. Fertilizer and four micronutrients plus copper spray (0.8 pound per acre copper chloride)	302
6. Fertilizer and four micronutrients plus 30 pounds per acre copper chloride in fertilizer	251
L.S.D. at the 5% level	47.2
L.S.D. at the 1% level	64.4

* An 0-12-12 at 700 pounds per acre made from treble superphosphate (48%) and potassium sulfate. Calcium sulfate (98% $CaSO_4.2H_2O$) at the rate of 180 pounds per acre and magnesium chloride at the rate of 100 pounds were added to the fertilizer. Fertilizer applied in the furrow under the oat rows before seeding. Commercial sodium nitrate at 150 pounds per acre was applied as a topdressing.

** The four micronutrients were mixed in the fertilizer at the following rates in pounds per acre: zinc chloride, 10; manganese chloride, 10; boric acid, 2; and molybdic acid, 0.4.

The oats were harvested in the vegetative stage just before heads began to form on April 4, 1949.

The yield of oats (Table 3) was significantly increased by copper chloride any way it was applied. The highest yield was obtained from the spray treatment where only 0.8 pounds per acre were applied. The yield with 30 pounds per acre of copper chloride in the soil was not significantly better, statistically, than 10 pounds. Flowers of sulfur mixed in the soil before planting the oats signicantly increased the yield, even though one would assume the nutrient requirements for sulfur would have been met by the potassium sulfate and the calcium sulfate in the fertilizer. It is probable that the flowers of sulfur had an indirect effect, possibly making some of the soil copper more available.

Manganese Deficiency of Oats

In January 1953 Floriland oats grown under field conditions on Arredondo loamy fine sand developed what appeared to be "grey-speck" (3 and 12) in a small circular area. The main part of the field was not affected. The soil was tested and the affected area had a pH of 7.2 while the remainder of the field had a pH of 5.1. A part of the circle was treated January 28, 1953, with 15 and 35 pounds per acre of manganese sulfate and the other part was not. The oats in the untreated area almost all died, while the ones where the manganese was applied recovered. Thus, the abnormality appeared to be manganese deficiency. The high pH value and charcoals in the soil suggested that the cause was an over-limed condition due to burning of logs at some previous time.

A similar condition of oats has been observed in spots where piles of tung trees have been burned and near lime rock roads.

Rye, Barley and Wheat Experiments

A series of field tests were begun in the fall of 1947 to determine the effect of micronutrients on the growth of other small grains. These tests were alike in design and the treatments applied to each crop were the same. The plots were 3 x 20 feet or 1/726 acre and contained two rows of small grain 18 inches apart. Two rows of small grain without treatment were seeded between the plots as borders. The treatments, which are given in Table 4, were replicated four times in randomized blocks for each crop.

Calhoun (awnless) barley was seeded in one test, Abruzzi rye in another, and Sanett wheat in the third December 8, 1947. These crops grew to maturity and were harvested April 30, May 4, and May 7, 1948, respectively.

The areas where wheat and rye were grown were seeded to crotalaria in the summer as a cover crop and in the fall the plots were again prepared for seeding. The same treatments in the same way as originally were applied to these plots, and on November 30, 1948, Florida Black rye was seeded where wheat had been grown and Abruzzi rye was seeded after itself. These crops were harvested at maturity. The results for both 1948 and 1949 are given in Table 4.

No difference was observed in the appearance of the rye as it grew, but where copper was not applied the barley appeared abnormal and

exhibited characteristics similar to those previously described for oats (7). The wheat without copper treatment exhibited similar characteristics but not to as marked degree as the barley.

TABLE 4.—EFFECT OF MICRONUTRIENTS AND SULFUR ON MEAN YIELD IN BUSHELS PER ACRE OF RYE, BARLEY, AND WHEAT.

Treatment	Abruzzi Rye (1948)	Florida Black‡ Rye (1949)	Abruzzi‡ Rye (1949)	Barley (1948)	Wheat (1948)
1. No treatment	5.4	2.1	0.3	0.1	4.5
2. Micronutrients*	6.1	3.6	0.4	0.2	4.1
3. Fertilizer**	10.4	3.8	0.8	0.2	3.0
4. Fertilizer plus micronutrients	10.5	4.8	0.7	9.3	12.3
5. Fertilizer plus micronutrients except copper	9.5	4.9	0.6	0.1	2.7
6. Fertilizer plus copper and iron	10.5	4.0	0.7	6.3	13.3
7. Fertilizer plus micronutrients except iron	10.9	4.3	0.8	9.7	13.6
8. Fertilizer (without sulfates) † plus micronutrients	11.5	4.2	1.3	5.7	11.5
L.S.D. at the 5% level	2.6	1.3	0.4	4.9	3.0
L.S.D. at the 1% level	3.5	1.7	0.6	6.6	4.1

* Micronutrients were applied at the following rates in pounds per acre: copper chloride, 10; manganese chloride, 10; zinc chloride, 10; boric acid, 2; ferrous chloride, 2, and molybdic acid, 0.5. They were mixed with the fertilizer except when fertilizer was not applied, in which case they were mixed with inert sand and applied the same as the fertilizer.

** An 0-12-12 at 500 pounds per acre prepared from treble superphosphate (48%) and potassium sulfate. Magnesium chloride and calcium sulfate (98% $CaSO_4.2H_2O$) were added at 80 and 110 pounds per acre, respectively. The fertilizer was put in a furrow under the row before seeding. Topdressings, one of 100 pounds and another of 150 pounds per acre, of commercial sodium nitrate were applied to all plots receiving fertilizer.

† Equivalent amounts of potassium chloride and calcium chloride were substituted for potassium sulfate and calcium sulfate in the fertilizer.

‡ Treated the same the previous year when rye or wheat was grown.

Fertilizer had essentially no effect on the yield of wheat without micronutrients (compare treatments 1 and 3, Table 4). The group of micronutrients highly significantly increased the yield (compare treatments 3 and 4), but the increase was due to the copper (compare treatments

TABLE 5. -EFFECT OF MICRONUTRIENT TREATMENTS IN FACTORIAL TEST ON MEAN YIELD OF TWO VARIETIES IN BUSHELS SHELLED CORN PER ACRE.

Treatment in 1947 (Repeated in 1948)	Whatley's Prolific in 1947	Florida W-1 in 1948†
1. Fertilizer only*	39.2	40.3
2. Cu**	50.3	42.6
3. B	37.1	30.2
4. Cu and B	49.4	34.2
5. Mn	35.4	24.9
6. Cu and Mn	46.0	29.2
7. B and Mn	36.8	27.5
8. Cu, B and Mn	41.2	22.7
9. Zn	42.8	32.0
10. Cu and Zn	49.8	42.9
11. B and Zn	40.7	31.2
12. Cu, B and Zn	50.3	39.2
13. Mn and Zn	38.8	31.2
14. Cu, Mn and Zn	44.4	38.7
15. B, Mn and Zn	34.2	22.7
16. Cu, B, Mn and Zn	44.4	30.8
17. Mo	39.8	32.4
18. Cu and Mo	45.8	41.6
19. B and Mo	41.1	34.1
20. Cu, B and Mo	50.3	35.5
21. Mn and Mo	39.4	32.5
22. Cu, Mn and Mo	45.8	31.2
23. B, Mn and Mo	34.3	21.1
24. Cu, B, Mn and Mo	46.8	33.9
25. Zn and Mo	38.7	32.1
26. Cu, Zn and Mo	44.6	39.6
27. B, Zn and Mo	37.7	26.8
28. Cu, B, Zn and Mo	44.3	35.4
29. Mn, Zn and Mo	39.7	24.0
30. Cu, Mn, Zn and Mo	44.1	36.3
31. B, Mn, Zn and Mo	36.1	27.8
32. Cu, B, Mn, Zn and Mo	45.9	30.0
Ave. without copper	38.2	29.4
Ave. with copper	46.5	35.2

Differences due to copper highly significant both years. Other differences not significant, except Mn decreased the yield of Fla. W-1 corn especially.

* An 0-12-12 at 600 pounds per acre prepared from treble superphosphate (48%) and potassium chloride was applied to all plots. Calcium sulfate (98% $CaSO_4 2H_2O$) and magnesium sulfate were added to the fertilizer at the rate of 110 pounds and 80 pounds per acre, respectively. The fertilizer was mixed in a furrow under the row before seeding. The nitrogen (48 pounds per acre) was in three sidedressings, one-third each time. The first was sodium nitrate applied soon after seeding and the other two were uramon applied during the growing season.

** The micronutrients were applied at the following rates in pounds per acre: copper chloride, 10; manganese chloride, 10; zinc chloride, 10; ferrous chloride, 2; boric acid, 2; and molybdic acid, 0.5. These were mixed with the fertilizer. Ferrous chloride was applied to all plots.

† Florida W-1 followed the previous crop of corn and treatments repeated as originally. Furthermore, lupines were seeded in these plots in the fall of 1947 and again were given the same treatments except only one-third of the total nitrogen.

4 and 5). Fertilizer without sulfates decreased the yield slightly but not significantly (compare treatments 4 and 8).

The results for the barley were similar to those for wheat. The fertilizer without sulfates decreased the yield of barley 3.6 bushels (compare treatments 4 and 8, Table 4), but this difference is slightly below the significant level.

The yield of Abruzzi rye was poor in 1949 (Table 4) but even so the trends were similar in both 1948 and 1949. Fertilizer increased the yields significantly both years, but none of the micronutrient treatments had any significant effect either year. The fertilizer without sulfates produced a larger yield than with sulfates, but the difference is significant only in 1949. This means little in a practical way since the yield was low.

The yield of Florida Black rye (Table 4) was low in 1949; in fact, rye in this area usually produces low grain yields. None of the treatments had much effect on yield, but the group of micronutrients alone (compare treatments 1 and 2, Table 4) significantly increased the yield while the fertilizer alone (compare treatments 1 and 3) also significantly increased the yield. However, fertilizer with the group of micronutrients was not significantly better than fertilizer alone (compare treatments 3 and 4). None of the combinations with fertilizer had a significant effect compared to fertilizer alone.

The trends for straw yields of the wheat, barley and rye were similar to those for grain so the data will not be presented.

CORN

Field Tests

Land was prepared in the spring of 1947 and two tests were begun to evaluate primarily the effect of micronutrients on the yield of corn. One of these was a 2^5 factorial experiment duplicated with the fourth order interaction confounded with blocks, as described by Yates (13). The plots were 12 x 20 feet and contained three rows of corn. The treatments which are given in Table 5 were mixed in the furrow under the corn rows.

In the other test a variety of treatments were randomized in four blocks. These treatments are given in Table 6. The size of the plots and manner of treatment application were the same as in the factorial test.

Whatley's Prolific was planted March 29, 1947, in both tests. The ears of corn were harvested when they were mature.

After the corn was harvested, bitter blue lupine was seeded. The same treatments were applied for lupines as corn, except only a third of the nitrogen.

Cold damaged the lupines before they had made much growth. Therefore, they were plowed under in mid-winter, and the soil prepared for corn again.

Florida W-1 corn was planted March 19, 1948 in both the factorial and randomized block tests. This corn had the same treatments as previously, applied in the same manner.

The corn was harvested at maturity and the yields of both tests for the two years are given in Table 5 and 6.

The two varieties of corn both years appeared to grow normally.

In the factorial experiment (Table 5) copper increased the yield of both varieties about 20 per cent. With the exception of manganese—which decreased the yield of Florida W-1 corn about 18 per cent—other treatments had no pronounced effect.

TABLE 6. Effect of Treatment in Randomized Block Experiment on Mean Yield of Two Varieties in Bushels Shelled Corn per Acre.

Treatments in 1947 (Repeated in 1948)	Whatley's Prolific 1947	Florida W-1 1948‡
1. No treatment	38.6	31.7
2. Micronutrients*	40.6	27.5
3. Fertilizer**	38.3	38.1
4. Fertilizer + micronutrients	47.5	38.8
5. Fertilizer + high nitrogen†	42.5	30.9
6. Fertilizer + high nitrogen and micronutrients	46 9	41.8
7. Fertilizer + micronutrients, but without calcium sulfate	48.4	33.6
8. Fertilizer + micronutrients, but without magnesium chloride	46.4	42.7
9. Fertilizer + micronutrients, but equivalent calcium chloride for calcium sulfate	48.6	31.8
10. Fertilizer + micronutrients except iron	44.3	36.0
L.S.D. at the 5% level	4.6	9.3
L.S.D. at the 1% level	6 3	12.6

* All six micronutrients at the rates indicated in Table 5. They were mixed with the fertilizer.

** Same fertilizer, rate, and manner of application as given in Table 5, except magnesium chloride at 80 pounds per acre was added to the fertilizer in place of magnesium sulfate.

† Double nitrogen or a total of 96 pounds of nitrogen per acre.

‡ Treatments repeated for this crop of corn which was grown in same plots as last year. Lupines were also seeded in the plots in the fall of 1947, and were then given the same treatments, except only one-third of the total nitrogen.

In the randomized block test, fertilizer alone or the micronutrients without fertilizer had no significant effect on yields of Whatley's Prolific (compare treatments 1, 2 and 3, Table 6). With fertilizer, micronutrients highly significantly increased the yield (compare treatments 3 and 4). Leaving sulfates or magnesium out of the fertilizer had no significant effect, and 48 pounds of nitrogen was as effective as 96 pounds.

The results for Florida W-1 in the randomized block test (Table 6) are more irregular as shown by the larger differences required for significance. Fertilizer significantly increased yields when treatments 2 and 4 are compared, but micronutrients had no effect when treatments 3 and 4 are compared. However, micronutrients had a significant effect when treatments 5 and 6 are compared. In any case, the results in this part of the corn tests are confusing and perhaps should not be emphasized.

Observations on Corn Leading to Greenhouse Tests

"White bud" of corn as observed by the authors is a light color—often almost white and watery appearance in irregular spots—of the blades in the bud of young corn. Plants sometimes have a purplish color on parts of the blades. As the corn grows older the blades frequently become striped, and plants have a tendency to grow out of this condition, although they may be permanently affected and stunted. Young affected plants have been marked and observed later in the season. As the plants grew out of this condition the lower blades, which were in the bud at the time white bud appeared, were fired or exhibited symptoms similar in some respects to the lower blades of potash deficient plants (3).

The authors have repeatedly planted corn between the hills of affected plants under field conditions and these replants have not shown white bud. Furthermore, corn grown in the greenhouse on soil from affected areas never developed these symptoms. However, these preliminary tests were conducted late in the corn-growing season. These circumstances make one suspect that the season or temperature has an influence. Facilities for the control of temperature were not available, so it was decided to conduct experiments on a variety of soils at the greenhouse in the open exposed to the cool temperatures of early spring.

Corn on Arredondo Loamy Fine Sand at Greenhouse

This soil was taken from a part of the "Cracker Farm", Florida Agricultural Experiment Station, Gainesville, Florida, where white bud of corn was known to occur. It was from a location which had a pH of 5.4 and by rapid tests contained in pounds per acre the following amounts of relatively available nutrients:[3] CaO, 210; P_2O_5, 39; K_2O, 84; and MgO, less than 50. No fertilizer had been applied to it since about 1930, and possibly little before then.

The soil was brought from the field in late January, 1952, trash removed, thoroughly mixed, and put into 2-gallon glazed pots, 24.2 pounds of soil per pot. Glass wool had been put over the drainage opening to prevent soil spillage. These pots were placed on a low bench outside the greenhouse. The treatments (listed in Table 7), prepared by mixing the chemicals, were applied broadcast two inches under the surface February 11, 1952. They were randomized without blocks and replicated three times.

Dixie 18 corn was planted the same day. After a stand was assured the corn was thinned to three plants per pot.

A total of 150 pounds per acre of potassium nitrate and 400 pounds of ammonium nitrate were applied as a topdressing to the growing corn of all pots except the ones without treatment. Also, 75 pounds per acre of magnesium chloride was applied in the same way to pots that had magnesium in the treatments. These chemicals were dissolved in water and applied in solution. Fractions of the total amounts were applied from time to time as appeared desirable.

The corn was harvested in the vegetative stage when it was about two feet tall May 7, 1952.

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[3] Values for rapid tests through the courtesy of the Soil Testing Laboratory, Soils Department, Florida Agricultural Experiment Station, Gainesville, Florida.

TABLE 7.—EFFECT OF TREATMENT APPLIED TO ARREDONDO LOAMY FINE SAND IN POTS ON MEAN DRY FOLIAGE YIELD OF CORN.

Treatment	Yield in Grams per Pot	
	First Harvest	Second Harvest
1. No treatment	4.3	2.3
2. Complete*	43.0	34.0
3. Complete, except micronutrients	36.0	35.7
4. Complete, except zinc	30.7	36.3
5. Complete, except copper	39.7	32.0
6. Complete, except sulfur**	32.3	8.7
7. Complete, except magnesium	42.0	35.3
L.S.D. at the 5% level	10.1	4.8
L.S.D. at the 1% level	14.0	6.6

* Reagent grade chemicals used at the following rates in pounds per acre (considering 2,000,000 pounds of soil an acre): Potassium nitrate, 200; mono-calcium phosphate, 200; calcium sulfate, 300; calcium lactate (where sulfur was not in the fertilizer), 528; magnesium chloride, 150; copper chloride, 15; zinc chloride, 15; manganese chloride, 15; boric acid, 1.5; and sodium molybdate, 0.75.

** Sulfur eliminated from treatment by substituting equivalent amount of calcium lactate for calcium sulfate.

Without disturbing the soil after harvest of the corn the pots were again given the original treatments applied to the surface and thoroughly watered except no micronutrients were reapplied. This was done May 13, 1952, and Dixie 18 was again planted the same day. After a stand was assured the corn was thinned to two plants per pot.

A total of 200 pounds per acre of potassium nitrate and 150 pounds of ammonium nitrate were applied as a topdressing to the growing corn of the second crop in the same way as previously explained.

The second crop of corn was harvested in the vegetative stage July 7, 1952. The yields for both crops are given in Table 7.

The growth characteristics of the first harvest of corn in some respects differed from those of the second harvest. Corn in the first harvest with a complete treatment including the micronutrients appeared to grow normally. Without treatment it was small, pale yellow in color, but without striking distinguishing characteristics. In most cases where zinc was not in the fertilizer white bud as previously described developed, but it was irregular, and not all plants were affected. There was a tendency for affected plants to grow out of this condition. In that case the edges of the lower blades became scorched or fired similar to the lower blades of potash deficient corn (3). The blades of corn grown without sulfur in the fertilizer developed a fine stripe when the corn was about 5 inches tall. As the plants grew the stripes disappeared rather quickly and the corn became a uniform pale yellow color with the mid-ribs and base of the plants a pronounced purplish color.

The second crop of corn did not develop white bud in any case and the other symptoms were the same as for the early crop.

The foliage yield of the first harvest (Table 7) for the no treatment was highly significantly lower than any other treatment. Where zinc or sulfur was left out of the treatment there was a significant decrease in

yield. Leaving the five micronutrients out of the treatments decreased the yield, but the decrease was not significant. Since zinc was one of the five micronutrients, the reason for this lack of significance is not clear, but possibly is related to the high variability of the experiment.

In the second harvest (Table 7) the lack of sulfur highly significantly decreased the yield, but the lack of zinc had no effect on yield. In other words the effectiveness of the zinc application changed with the time of the year.

Corn on Hernando Fine Sand at Greenhouse

This soil was taken from a farm near Alachua, Florida, on February 14, 1952, and brought to the greenhouse. The soil had a pH value of 5.7, and the farmer had never used much fertilizer.

The trash was removed from the soil and the soil thoroughly mixed and potted as in the previous experiment February 15, 1952. Each pot contained 19.18 pounds of soil. The pots were put on a bench in the open.

The treatments (listed in Table 8) were similar but not identical to the ones in the previous experiment. They were prepared by mixing the chemicals with the exception of ammonium nitrate and were applied broadcast 2 inches below the surface. The ammonium nitrate was dissolved in water and applied at the same level. These treatments were applied March 5, 1952. There were four pots with each treatment and they were randomized without blocks.

TABLE 8.—Effect of Treatment Applied to Hernando Fine Sand in Pots on Mean Dry Foliage Yield of Corn.

Treatment	Yield in Grams per Pot	
	First Harvest	Second Harvest
1. No treatment	4.0	3.0
2. Complete*	30.3	21.5
3. Complete, except copper	30.8	22.5
4. Complete, except zinc	26.5	22 8
5. Complete, except sulfur**	12.5	11.5
6. Complete, except potassium	23.8	11.5
7. Complete, except magnesium	27.3	17.8
L.S.D. at the 5% level	4.0	3.7
L.S.D. at the 1% level	5.5	5.0

* Reagent grade chemicals at the following rates in pounds per acre (considering 2,000,000 pounds an acre): Ammonium nitrate, 150; mono-calcium-phosphate, 140; potassium chloride, 125; calcium sulfate, 300; calcium lactate (where sulfur was not in the fertilizer, 528; magnesium chloride, 150; copper chloride, 15; zinc chloride, 15; manganese chloride, 15; boric acid, 2; and sodium molybdate, 0.5.

**Sulfur eliminated from treatment by substituting equivalent amount of calcium lactate for calcium sulfate.

Dixie 18 corn was planted March 5, 1952, and after a stand was assured thinned to three plants per pot. The growing corn received two topdressings of 150 pounds per acre of ammonium nitrate each, except the no treatment ones.

The corn was harvested May 7, 1952.

The original treatments, with the exception of micronutrients, were reapplied on the surface of the soil without breaking or cultivating it. Dixie 18 corn was again planted May 29, 1952, and when a stand was assured thinned to four plants per pot. A total of 350 pounds per acre of ammonium nitrate was applied to the corn in all pots, except the no treatment ones, as a topdressing during the growing period.

This second crop of corn was harvested July 19, 1952, and the results for both harvests are given in Table 8.

The growth characteristics of the corn in this experiment were similar to the corn in the previous experiment. Corn without treatment was small, pale yellow, and it was rather difficult to distinguish any other characteristics. Where zinc was not applied, white bud developed in the first crop, but not in the second. Without sulfur in the treatment both crops of corn developed symptoms which were described in the previous test. Without potassium both crops of corn developed typical potassium deficiency symptoms (3).

Omission of zinc decreased the yield (Table 8) of the first corn crop, but the difference was just under significance (compare treatments 2 and 4, Table 8). The lack of zinc had no effect on the yield of the second crop, again suggesting that the time of the year had an effect on the response to zinc. The yield of both crops was highly significantly decreased when either sulfur or potassium was not applied. Magnesium significantly increased the yield of the second crop of corn.

Corn on Klej Fine Sand at Greenhouse

The soil was obtained from the Station Farm, Live Oak, Florida, about the middle of March, 1953, and brought to the greenhouse. It was prepared as usual and put in four-gallon glazed pots, 40 pounds of soil per pot. The pots were arranged on benches outside of the greenhouse April 15, 1953.

The soil had a pH value of 5.19, and the relative amount of vailable nutrients, pounds per acre, were as follows: CaO, 112; MgO, 33; P_2O_5, 76; and K_2O, 50.

This test was more elaborate than the other greenhouse ones as indicated by the treatments which are given in Table 9. The proper chemicals were mixed and applied broadcast at about the 3-inch deep level, with the exception of ammonium nitrate, disodium ferrous salt of ethylenediamine tetraacetic acid, and disodium salt of ethylenediamine tetraacetic acid. The latter two were applied separately broadcast about one-half inch deeper. The ammonium nitrate was dissolved in water and applied to the surface. The treatments (Table 9) were randomized in four blocks and applied April 29, 1953. Dixie 18 corn was planted immediately and thinned to three plants per pot as soon as a stand was assured.

The corn was topdressed with 75 pounds of potassium nitrate and 150 pounds per acre of ammonium nitrate. It was harvested June 4, 1953, and the results are given in Table 9.

There was not a noticeable difference in the appearance of the growing corn with the exception of where sulfur was not applied. In that case the corn was yellow as has been described in other tests.

None of the different treatments had any large effect on yield (Table 9). Omitting sulfur (compare treatments 2 and 3, Table 9) decreased

yield, but this reduction was just under significance statistically. The various micronutrients and the group of more unusual elements had no significant effect on yield. This corn was grown late in the season; whether the time of the year had anything to do with the lack of response to zinc is not known.

TABLE 9.—EFFECT OF TREATMENT APPLIED TO KLEJ FINE SAND ON MEAN DRY FOLIAGE YIELD OF CORN.

Treatment	Yield Grams per Pot
1. Complete but without calcium sulfate	31.4
2. Complete*	33.4
3. Complete but without sulfur**	30.0
4. Complete (200 lbs. calcium sulfate)	34.6
5. Complete (200 lbs. calcium sulfate) without micronutrients and strontium	36.1
6. Complete (200 lbs. calcium sulfate) without copper	37.5
7. Complete (200 lbs. calcium sulfate) without zinc	31.4
8. Complete (200 lbs. calcium sulfate) without manganese	32.4
9. Complete (200 lbs. calcium sulfate) without boron	37.5
10. Complete (200 lbs. calcium sulfate) without molybdenum	37.3
11. Complete (200 lbs. calcium sulfate) without strontium	34.6
12. Complete (200 lbs. calcium sulfate) without magnesium	36.1
13. Complete (200 lbs. calcium sulfate) with oxide source of copper†	34.8
14. Complete (200 lbs. calcium sulfate) plus iron E.D.T.A.‡	32.4
15. Complete (200 lbs. calcium sulfate) plus E.D.T.A.‡	36 0
16. Complete (200 lbs. calcium sulfate) plus unusual elements§	34.8
L.S.D. at the 5% level	3.8
L.S.D. at the 1% level	5.2

* Reagent grade chemicals applied at the following rates in pounds per acre (2,000,000 pounds of soil considered an acre): Potassium nitrate, 145; ammonium nitrate, 28; mono-calcium phosphate, 142; calcium sulfate, 100 or 200; calcium lactate (where substituted for 100 pounds calcium sulfate), 176; magnesium acetate, 50; copper chloride, 4; manganese chloride, 4; zinc chloride, 4; boric acid, 1; sodium molybdate, 0.2; and strontium chloride, 2.

** Sulfur eliminated from treatment by substituting equivalent amount of calcium lactate for the 100 pounds calcium sulfate.

† Copper oxide at 3 lbs. per acre; material supplied by Calumet and Hecla, Inc.

‡ Disodium ferrous sailt of ethylene diamine tetraacetic acid and disodium salt of ethylene diamine tetraacetic acid at 4 lbs. per acre. Material supplied by Bersworth Chemical Company.

§ Acre rates in pounds were: vanadyl chloride, 0.2; columbium pentoxide, 0.2; cobalt chloride, 1; nickel chloride, 1; sodium iodide, 0.2; rubidium chloride, 0.2; sodium dichromate, 0.2; gallium nitrate, 0.2; cerus nitrate, 0.2; sodium fluoride, 0.2; tungstic acid, 0.2; and tin chloride, 0.2.

BITTER BLUE LUPINES AFTER PEANUTS

A field experiment was conducted in 1948 to determine the effect of copper and other treatments on the yield of peanuts, results of which have been published (9). At this time all that will be said is that a small amount of copper—either in the fertilizer or as a spray—greatly increased the yield on Arredondo loamy fine sand.

The plots were $6\frac{1}{3}$ x 15 feet and contained two rows of peanuts. The treatments, which are given in Table 10, were replicated four times and randomized in blocks.

After the peanuts had been harvested, the land was again prepared. In late November bitter blue lupines seeded where the Dixie Runner had been grown. The lupine seed were inoculated with the proper legume organism and planted in rows 19 inches apart. Fertilizer and micronutrients as indicated in Table 10 were reapplied before seeding.

TABLE 10.—EFFECT OF TREATMENT ON MEAN YIELD IN POUNDS PER ACRE GREEN WEIGHT OF BITTER BLUE LUPINES FOLLOWING PEANUTS.

Treatment of Peanuts	Yield Lupines† Following Peanuts Pounds per Acre
1. No treatment	16,381
2. Fertilizer*	13,558
3. Fertilizer plus micronutrients**	18,880
4. Fertilizer plus micronutrients except copper	14.285
5. Fertilizer plus copper	19,173
6. Fertilizer plus micronutrients except molybdenum	17,566
7. Fertilizer plus molybdenum	12.336
8. Fertilizer plus copper and molybdenum	19,479
9. Micronutrients	25,430
L.S.D. at the 5% level	4,202
L.S.D. at the 1% level	5,695

* 2-12-12 at 500 pounds per acre prepared from uramon, treble superphosphate (48%) and potassium chloride. Calcium sulfate and magnesium sulfate at 100 and 80 pounds per acre, respectively, were added to the fertilizer. The fertilizer was worked in the soil in a broad strip about 15 inches wide, where the rows were to be, previous to planting.

** The micronutrients were mixed with the fertilizer and were at the following rates in pounds per acre: copper chloride, 10; zinc chloride, 10; manganese chloride, 10; boric acid, 2; and molybdic acid, 1.

† Lupine treated same as peanuts except no nitrogen in the fertilizer mixture, and sodium nitrate at 150 pounds per acre applied February 1, 1949, to all plots having fertilizer. The fertilizer was broadcast and worked in the soil before seeding.

There was no difference in the appearance of the lupines before harvest. They were harvested April 19, 1949, and the results are given in Table 10. Copper highly significantly increased the yield (compare treatments 2 and 5, Table 10). The group of micronutrients significantly increased the yield (compare treatments 2 and 3), and this increase appears to be due largely to copper (compare treatments 3 and 5). Furthermore, the group of the micronutrients was highly significantly better without the fertilizer than with it (compare treatments 9 and 3). Why the fertilizer should be detrimental is not clear.

TOBACCO

A number of experiments have been conducted with tobacco, the results of which will be given in another publication. However, micronutrients have not influenced the yield of tobacco in those tests.

GENERAL DISCUSSION AND CONCLUSIONS

Both field and greenhouse experiments dealing with micronutrients and sulfur were conducted. The field tests were on Arredondo loamy fine sand.

Other soils were utilized in the tests at the greenhouse. In establishing the essentiality of a micronutrient for a soil under greenhouse conditions, four conditions are of great importance, namely: (1) water supply essentially free of micronutrients, (2) purified chemicals in the treatments, (3) containers essentially free of micronutrients, and (4) protection against dust and other contamination. These greenhouse tests were conducted as carefully as facilities would permit. However, because of the exacting nature of micronutrient tests, reliance should be placed mainly on positive results with those nutrients in these pot experiments.

In these field experiments, copper in the fertilizer materially increased the yield of oats, wheat, barley, cowpeas, peanuts (9), bitter blue lupines, and moderately increased the yield of corn, but had no effect on the yield of rye. The small grains, except rye, and peanuts (9) exhibited marked deficiency symptoms when copper was not in the treatment. A small amount of copper was adequate and a spray was effective on oats and peanuts (9).

In the field tests zinc had no observable effect on corn. This was to be expected since zinc had been applied in the previous fertilizer treatments. An early crop of corn on two soils at the greenhouse had characteristic white bud when zinc was not applied. A second crop of corn, planted on the same soils without disturbing them, in the same pots did not have white bud even where zinc was not applied. A build-up of the zinc supply of the soil at the greenhouse through dust or other means might be possible, but it does not seem probable. Both field results and greenhouse tests suggest that something about the time of the year has an influence on the development of zinc deficiency of corn. These results are somewhat different from those reported by others (1 and 2).

Manganese in a factorial test suppressed the yield of corn. In these experiments it had no other observable effect except in one case where oats apparently developed "grey speck" (3 and 12) in an over-limed situation. An addition of manganese corrected the obnormality.

No effect was observed for boron.

Molybdenum caused cowpeas and peanuts (9) to be a darker green color, but had no effect on yields.

Several of the more unusual elements, including vanadium, were not effective in one experiment.

Even though sulfur had been applied in previous treatments, there was a suggestion in some of the results of the field tests that sulfur in the fertilizer was beneficial although the differences were not statistically significant. At the greenhouse, on soil where sulfur had not been applied previously, it greatly increased the yields of corn. These tests as well as published results (4, 10 and 11) indicate that sulfur deficiency may be of great importance under some conditions in Florida.

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MANGANESE REQUIREMENTS OF POTATOES AND TOMATOES ON MARL SOILS

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Manganese is generally included in fertilizers to be used for potatoes and tomatoes on the marl soil of Dade County. In the past 25 years, this practice has become so well established that it is seldom questioned. It seemed possible that in many instances sufficient manganese had been added to the soil so that there was enough to grow a good crop without further addition of manganese in the fertilizer. There was also the possibility that the long continued use of large amounts of manganese could lead to the accumulation of toxic concentrations of soil manganese. Thus, it appeared worthwhile to conduct field trials with these vegetables using various rates of application of manganese in the fertilizer to determine whether or not either or both of these possible situations did in fact exist.

PREVIOUS WORK

Manganese deficiency in potatoes grown on marl soils was first reported by Skinner and Ruprecht (3) in 1930. They described the symptoms of deficiency as leaf chlorosis and severe stunting, in some cases followed by death of the plants. Those plants which survived produced only small and unsaleable tubers. In their experiments, 50 to 100 pounds of manganese sulfate per acre corrected the deficiency. They tested the residual effects of manganese by planting a second crop in the same season. Corn on plots where the fertilizer for the preceding tomato crop contained manganese grew better than corn on plots where the tomato fertilizer contained no manganese. There was not sufficient manganese available on these plots to meet all of the needs of the corn, since response was obtained from manganese added to the corn fertilizer.

In further trials, Fifield and Wolfe (1) attempted to establish the optimum rate of application of manganese and also studied the residual effects. They observed no distinctive deficiency symptoms in the leaves of the potato plant on the check plots in their experiments. They tested rates of application from 0 to 45 pounds of MnO per acre using manganese sulfate as the source. Maximum yields were obtained with 22.5 pounds of MnO per acre. Increasing the rate of application to 45 pounds of MnO per acre resulted in a slight depression in yield. In the test of the residual effects of the application of manganese, there was a definite carry over from one year to the next; but, during the four years the test was conducted, the maximum response was obtained from the annual application of manganese sulfate. They concluded that after five years manganese sulfate might be left out of the fertilizer for at least one year without reducing yields.

Skinner and Ruprecht (3) were the first to recognize manganese deficiency on tomatoes grown on marl soils. The symptoms they described

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were similar to those in potatoes. The leaves were extremely chlorotic and in many cases the plants died. Crop failure was almost certain when fertilizer without manganese was used. The deficiency could be prevented by the liberal use of stable manure or by the application of 75 to 100 pounds of manganese sulfate per acre. Besides demonstrating the effectiveness of manganese sulfate in correcting this deficiency, they tested several managanese minerals and industrial by-products as a source of this element for tomatoes, none of which showed any merit.

In a recent study of different sources of manganese Fiskel, Forsee, and Malcolm (2) compared four different manganese compounds and a no-manganese check in virgin marl. The compounds tested were manganous sulfate, manganous oxide, manganese dioxide, and manganous EDTA. Distinctive symptoms of deficiency were observed on the tomatoes grown without manganese. The leaves were chlorotic with some interveinal necrosis. Yields were markedly poorer without manganese. The manganous sulfate and manganous oxide were the best sources of manganese tested.

POTATO EXPERIMENT

The potato experiment described in this paper was set up to determine the effect of different rates of application of manganese over a period of years. It was located at the East Glade Farm of the Sub-Tropical Experiment Station, six miles east of Homestead and only one mile from open salt water. The soil is a marl of moderate depth with a pH of approximately 7.8. It is subject to salt intrusion. The chloride content of the soil during the course of the experiment ranged from 100 to 2,000 ppm. The land was used for various experiments for a period of 15 years before this manganese experiment was established. In the fall of 1945 the farm was flooded with seawater and severely salted. Most of the effects of this flooding had disappeared by the fall of 1948 when this experiment was set up.

Manganese was the only variable in this experiment. Technical manganese sulfate, the source of manganese, was mixed with the fertilizer. A zero manganese check and low, medium, and high rates of application of manganese were compared. The treatments were applied to the same plots each year. In the 1948-49 season the rates were 0, 37.5, 75, and 150 pounds of MnO per acre. These high rates of application were selected to build up the Mn content of the soil quickly. In the three succeeding seasons the rates were halved and 0, 18.75, 37.5, and 75 pounds of MnO per acre were applied. This provided nearly normal rates of application and still covered the range which might be found in commercial farming. During the four years, the total MnO applied in each treatment was 0, 93.75, 187.5, and 375 pounds per acre.

With the exception of manganese, fertilizers with the same analysis were used on all plots each year. The first year a 4-8-6 with 3 percent MgO was used and in the following years a 4-7-5 with 3 percent MgO. Half of the nitrogen in these mixtures was derived from tankage. Each year the fertilizer was applied by hand in bands approximately two inches from the seed pieces at planting time. The rate of application was 1,500 pounds per acre. The fertilizer applied in the 1951-52 season was analyzed for manganese on the flame photometer. The mixture without added manganese contained 0.2 percent MnO and supplied three pounds of MnO per acre.

The pest control program was similar to that used in commercial practice. Nabam plus zinc sulfate was used as the fungicide and DDT and parathion were the insecticides generally used.

The Bliss Triumph variety of potatoes was planted in November each year. The rows were 36 inches apart and the seed pieces were spaced 10 inches apart in the row. Each plot consisted of four rows and was 1/100 acre in area. Treatments were replicated four times. The potatoes were harvested in March each year, approximately 120 days after planting. A single row digger was used for the harvest and the potatoes from each plot were graded separately on a "Boggs" grader. The outside rows were discarded as buffers and yield records were secured from the two inside rows. After harvest, the ground was disced and sesbania was planted as a cover crop.

The yield data were evaluated statistically by the analysis of variance as described by Snedecor (4). Each year's data were analysed separately and the last three years' data were combined for analysis. The first year's data were not included in the combined analysis, since the rates of application of manganese were different.

There were no visible symptoms of deficiency or toxicity on any of the plots during the course of the experiment. The yield data are presented in Table 1. The value reported for each treatment is the average of the four replicates each year. The annual average yield from each treatment for the last three years is also given. Since no grade differences resulted from the treatments and grading introduced another source of error, the yield of all grades of tubers is reported. The average annual yield for the four years on all treatments was 90.7 pounds per plot, which is equivalent to 363 fifty pound sacks per acre. On the average, 86 percent of the tubers produced were marketable.

TABLE 1.—Yield of Potatoes from Manganese Fertilizer Experiment.
(Pounds per Plot*)

Treatment MnO Lbs./Acre	Yield				
	1949	1950	1951	1952	3 Year Avg.
0	106.9	90.5	99.4	59 8	83.2
18.75	....	101.6	95.5	63.2	86.8
37.5	108 3	101.7	95.4	61.2	86.1
75	110.3	97.9	95.7	52.4	82.0
150	108.8	....	....	....	....
L.S.D. at .05	NS	NS	NS	7.1	NS

* Yield in lbs./plot times 4 = yield in 50 lb. bags/A.

The treatments did not have a great effect on the yields. The check plots produced as much as the managanese-treated plots. Manganese is not readily leached from marl soils and a portion of it remains available as was indicated by the growth and appearance of the potatoes grown on the check plots without manganese for four years. A significant depression in yield in the fourth year was observed on the plots receiving the highest rate of application. It seems probable that this was the result of the accumulation of manganese on these plots, since they had received

375 pounds of MnO per acre during the course of the experiment although they already contained enough available manganese to meet the needs of the potato plants. No unusual conditions were observed which would have made the plants more susceptible to injury in this last season.

Two conclusions can be drawn from this experiment. On marl soils which have received manganese for fifteen or more years, further additions of manganese will not increase the yield of potatoes for at least four years. Furthermore, in spite of the high calcium carbonate content and high pH of the soil, the continued use of large amounts of manganese will cause toxicity.

TOMATO EXPERIMENT

The tomato experiment was located in south Dade County on the Highlands Farm of the Sub-Tropical Experiment Station. The marl soil on this farm is six to eight feet deep and has a pH of approximately 7.8. In preparing the land for cultivation, it was graded, ditched, and diked to permit the removal of excess water by pumping. Since this farm is located far from salt water there is no salt contamination. It had been farmed only four or five years before this experiment was established. The virgin soil used by Fiskel, Forsee, and Malcolm (2) on which tomatoes developed symptoms of extreme manganese deficiency came from near these plots.

The manganese treatments in this experiment were similar to those applied in the potato experiment. Using manganese sulfate as a source of manganese, a zero check and low, medium and high treatments were compared. These treatments were applied to the same plots each year. The amounts applied were 0, 50, 100, and 200 pounds of MnO per acre in 1949, and 0, 25, 50, and 100 pounds in each of the following three years to give a large initial application followed by rates covering the range used in commercial tomato farming. The total amounts applied over the four-year period in each treatment were 0, 125, 250 and 500 pounds of MnO per acre. All of the treatments were replicated four times. The plots were 1/100 of an acre in size and were separated by unplanted buffer strips. Fruits from all of the plants on each plot were harvested for yield records.

Only one basic fertilizer was used in this experiment. This was a 4-7-5 with 3 percent MgO with 50 percent of the nitrogen derived from tankage. Each year the fertilizer was applied at the rate of 2,000 pounds per acre. A portion of the fertilizer was applied at planting time and the remainder in two or three sidedressings. In all cases, it was applied by hand. With the exception of the first year, the fertilizer used in this experiment was the same mixture as that used in the potato experiment. The manganese impurity—0.2 percent—found in the 1952 fertilizer supplied four pounds of MnO per acre.

The plants for this experiment were grown in beds and transplanted to the field in January. They were set by hand two feet apart in rows six feet apart. Every year except 1950, compost was used to set them. That year the compost was omitted because it seemed to have masked the effects of the treatments the first year. So many plants were lost as a result of Rhizoctonia infection when no compost was used that compost was used the next two years, even though some masking of the effect of the manganese treatements may have resulted.

Two varieties of tomatoes were used in this experiment. For the first two years, Grothen's Globe—which is extremely susceptible to Fusarium wilt—was planted. As a result of wilt infection in 1950, which caused the early defoliation and premature death of the plants, a large proportion of the crop was unmarketable. Most of this unmarketable fruit ripened prematurely or was sunburned. In 1951 and 1952 a new and now commercially accepted variety, the Homestead, was planted. It combined wilt resistance with a vigorous vine habit which made it much more desirable than the Grothen's Globe.

The same general procedure was followed in harvesting the fruit each year. There were either three or four pickings each season, starting about April 1 and continuing until the fruit was no longer worth picking. The fruit from each plot was graded separately into marketable and cull fruit. Diseased, insect-damaged, and rat- and bird-damaged fruit were all included in the culls, although the injuries were not related to the nutrition of the plants. Prematurely ripe, sunburned, scarred, and misshapen fruit were also classed as culls.

Leaf samples for chemical analysis were taken in 1952. Sampling was done after the last picking so that there would be no chance of spreading virus diseases when they could affect the yields. A separate sample was taken from each plot. The third or fourth leaf from the tip of a main branch was selected each time, and twenty or more leaves comprised a sample. These samples were dried in a forced-draft oven at 85°C. The relatively low temperature was selected to minimize the decomposition of the samples during drying. The dried samples were ground to pass a 1 mm. sieve in a Wiley Mill which had been well used since sharpening. Sample contamination, even with iron, is not serious except after the knives are newly sharpened. The samples were wet-ashed with nitric and perchloric acids. Potassium, calcium, magnesium, and manganese were determined with a Beckman DU flame photometer. Phosphorus and iron were determined colorimetrically. The mineral elements other than manganese were determined to see whether the different manganese levels influenced the rate at which these elements were absorbed or whether the variation in some other element might be responsible for the plant response obtained.

Both the yield data and the results of the chemical analyses were examined statistically using the analysis of variance. The yield data for each year were analyzed separately and the data for the last three years were combined for analysis. This separation was made because the rates of application of manganese were twice as large in the first year as in the three succeeding years.

No visible symptoms of manganese deficiency or toxicity appeared on any of the plots during the four years the experiment was conducted. There were yield differences as a result of treatment, however. The yield data for the four years are shown in Table 2. The yearly figures are the average yields of the four plots on each treatment. The three-year averages cover only the last three years as explained earlier. No separation into grade is shown in this table, since there was no relationship between the proportion of marketable fruit and treatment and also because the classification of the fruit introduced another source of error.

Over the four-year period the yields were quite satisfactory. The overall average was 198 pounds of fruit per plot equivalent to 330 sixty

pound boxes per acre. The proportion of marketable fruit was low for various reasons. In most seasons the intense sunlight, heat and rain associated with the late spring caused sunburn, softening of the fruit, and premature ripening and encouraged rot. The poorest season was 1950 when the wilt exaggerated the effects of the weather. Only 28 percent of the fruit was marketable that year. The four-year average was 49 percent marketable.

TABLE 2.—YIELD OF TOMATOES FROM MANGANESE EXPERIMENTS.
(Pounds per Plot*)

Treatment MnO Lbs./Acre	Yield				
	1949	1950	1951	1952	3 Year Avg.
0	196.5	180.6	221.0	172.1	191.2
25	----	206.4	221.8	186.5	204.9
50	193.5	213.7	217.4	197 1	209.4
100	204 6	184.3	205.3	156.5	182.0
200	180.9	----	----	----	----
L.S.D. at .05	NS	21.5	NS	NS	5.3

* Yield in lbs./plot times 1.7 = yield in 60 lb. boxes/A.

Statistically significant differences in yield were obtained when the three-year averages were calculated and in the 1950 season. The plots receiving 25 and 50 pounds of MnO per acre produced significantly more fruit than the check. The plots receiving 100 pounds of MnO per acre produced significantly less than the plots which received 25 and 50 pounds per acre, and over the three-year period produced even less than the check. Although 1950 was the only year in which significant differences in yield were found, the three-year averages show that there was deficiency and toxicity in the other years as well.

The results of the leaf analyses are reported in Table 3. Each value is the average of four replicates. Only the differences in the manganese content were significant. The differences in the iron content were not close to significant, suggesting that the change in the manganese content had no influence on the iron content of the leaves. The close agreement between the manganese content of the leaves from plots treated with 50 and 100 pounds of MnO per acre indicates that the poor yields obtained at the higher rate of application were not the results of excessive absorption of manganese.

It is evident from the results of this experiment that a portion of the manganese in the marl soil is available to tomato plants. Even after four years without an appreciable amount of manganese being supplied by the fertilizer, the check plots showed no visible symptoms of manganese deficiency. The yields of the check plots were quite good although not as good as the yields from the plots receiving moderate amounts of manganese in the fertilizer. The leaf analyses show that the leaves from plants grown on the check plots contained appreciable amounts of manganese.

Although a portion of the soil manganese was available to the tomatoes, it was not sufficient to give maximum yields. The yields were significantly better where moderate amounts of manganese were applied

than on the checks. The leaves from the treated plots contained significantly more manganese than those from the check plots.

That significant reductions in tomato yields can result from the use of excessive amounts of manganese, even on a marl soil, was shown in the 1950 season and by the three-year averages. The analyses of the tomato leaves showed that there was no excessive absorption of manganese and no reduced absorption of iron and any of the major mineral constituents. The combined soil and fertilizer manganese probably was sufficient to cause direct injury to the plant roots. Under such circumstances the balance within the plant would not be disturbed.

TABLE 3.—COMPOSITION OF TOMATO LEAF SAMPLES FROM 1952 MANGANESE FERTILIZER EXPERIMENT.
(Percent)

Treatment MnO Lbs./Acre	P	K	Mg	Ca	Mn	Fe
0	0.33	2.7	0.59	1.9	0.0019	0.010
25	0.33	2.8	0.61	2.2	0.0038	0.012
50	0.36	2.8	0.59	2.1	0.0050	0.011
100	0.36	2.8	0.59	1.9	0.0048	0.011
L.S.D. at .05	NS	NS	NS	NS	0.0006	NS

SUMMARY AND CONCLUSIONS

Results of potato and tomato experiments show that manganese is available in the cultivated marl soils of Dade County. This was true in the potato experiment where the land had been farmed for a considerable number of years and also on the relatively new, but not virgin, land where the tomato experiment was conducted. On the old land, the soil supplied the manganese required by potatoes for four years. On the newer land, on the other hand, yields of tomatoes were increased by the addition of manganese to the fertilizer. Although no visible symptoms of manganese toxicity were observed in either potatoes or tomatoes, significant yield reductions, below the yields on the plots receiving moderate amounts, resulted from the use of 75 pounds of MnO per acre on potatoes and from 100 pounds of MnO per acre on tomatoes. Manganese should be added to the fertilizer in amounts sufficient to give the greatest return per acre but caution should be used to avoid larger amounts which might cause yield reductions.

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SOLUBILITY OF MANGANESE IN FLORIDA SOILS

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The availability of manganese in some soils of Florida has been altered by addition of manganese in the mixed fertilizer and likely by spray or dusting practices. Elsewhere the native manganese has supplied the crop requirements. Fortunately, the manganese content of most healthy crops has been found to have a wide range between the deficiency level and the toxicity level. Since foliar symtoms of manganese deficiency or toxicity are not commonly found, comparatively few manganese analyses of plants and of soils in Florida have been reported. Because of the complex nature of manganese relationships in the soil, it has proven difficult for research workers to correlate manganese solubility by different extracting solutions and availability to plants. However, considerable progress in our knowledge of this subject has been made.

As early as 1914, Sohngen (20) concluded that conversion of available manganous forms to manganic oxides was the cause of grey speck disease of oats grown on neutral or alkaline soils. He found that a variety of microorganisms were able to transform soluble manganous compounds into insoluble manganic oxides in the presence of neutral hydroxy acids on agar media, but that where acid conditions prevailed the hydroxy acids dissolved MnO_2. These results were confirmed by the work of Gerretsen (6) in 1937, and later by Leeper and Swaby (14) and Timonin (21). Mann and Quastel (15) concluded from percolation of neutral soils with dilute $MnSO_4$ that the oxidation of the manganese was by microorganisms. Drosdoff and Nikiforoff (4) found that the manganese in the iron-manganese concretions is present as the higher oxides, perhaps accumulated and oxidized by microbial action.

Evidence has been found that organic matter in the soil reacts with manganese. When soil organic matter was extracted at pH 6.0-6.5 with warm M/5 sodium metaphosphate, most of the total manganese was found in the filtrate, according to Heintze (7). When these solutions were electrodialized, the manganese was found at the anode; this indicated that manganese was present in a complex form. Dion and Mann (3) reported that soluble pyrophosphate and soil manganese reacted to form a complex compound which was extractable from the soil and contained manganese in the tri-valent state. Heintze and Mann (8) found that malate, salicylate, citrate and tartrate—each at pH 7—would extract a considerable fraction of the soil manganese, but succinate and benzoate would not. The above extracts were colored by extracted soil organic matter. The presence of manganese in a complex with soil organic matter was demonstrated in 1949 by Heintze and Mann (9). They postulated that manganese deficiency of plants on neutral and alkaline soils of high organic matter content and of adequate total manganese content was the result of complexing manganous ion in the organic matter. Jones

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and Leeper (12) and Hemstock and Low (10) have suggested that manganese might be held in a chelated form by the organic matter. If such is the case, then the extraction of soil manganese with the complex phosphates and with the hydroxy acids in the above instances might be interpreted to mean that these complexing extractants are capable of forming a stronger bonding with the manganese than is the organic matter.

Additional proof that soil organic matter may hold manganese in a chelate-like form has been furnished by research data obtained when other heavy metals were added to the soil. Replacement of manganese from a chelated-system would be accomplished if the heavy metal addition formed the more stable chelate-system. In 1926, Hudig et al. (11) reported that copper addition to a neutral soil increased the frequency of manganese deficiency symptoms on plants. Sherman et al. (18) found that copper addition to limed acid soils apparently retarded manganese oxidation and increased manganese availability. In 1949, Heintze and Mann (9) reported that the addition of $CuSO_4$, $CoCl_2$ or $ZnCl_2$ to ammonium acetate extracting solution resulted in an increase in manganese extracted. They offered the suggestion that either oxidation of soil organic matter or reduction of higher oxides of manganese was promoted by these heavy metal additions. The chelation theory explains these results adequately. Hemstock and Low (10) demonstrated that copper addition would release manganese from organic combination in Maumee sandy loam. Because the solubility of six different oxides of manganese was not appreciable in the above extracting solutions, the release of manganese was not coming from solubility of manganese oxides of these types in that soil. Toth and Romney (22) reported that high levels of copper and zinc increased the uptake of manganese by soybeans particularly in the soil at pH 4.6. Erratic results were obtained at higher pH values and also where cobalt and molybdenum were applied. In nutrient solution they reported that cobalt and iron increased manganese uptake by soybeans but not molybdenum or nickel.

The effect of soil pH on manganese availability is conceded to be important. All workers agree that liming an acid soil results in a lower uptake of manganese by the plant than on the unlimed soil. However, in calcareous soils, Boischot and Durroux (1) found the manganese to be fixed by absorption on the calcium carbonate particles. They concluded from their experiments that organic matter in these soils was responsible for the lack of manganese deficiency found in these soils. This might explain the effectiveness of manganese applied on the marl soils in Dade County.

METHODS

The solubility of manganese in some Florida soils is reported in this paper on the basis of exchangeable Mn by neutral normal $Ca(NO_3)_2$ extraction or purified N NH_4NO_3. Easily reducible Mn was extracted by the same $Ca(NO_3)_2$ solution containing 0.2 per cent hydroquinone. The method is that of Heintze (7) as modified by Jones and Leeper (12). For the sands, 10 grams of soil per 60 ml. of extracting solution were used and 6 grams for heavier textured and organic soils. After one hour of shaking, the sample was decanted to a centrifuge tube, and centrifuged until the supernatant was clear. Then, the supernatant was transferred to a 250 ml. beaker. The process of addition of 20 ml. portions of

N $Ca(NO_3)_2$, centrifuging and decanting of the supernatant was repeated four times. The sample solution was taken to dryness in the presence of 10 ml. of 70 per cent perchloric acid to destroy organic matter and hydroquinone. Manganese was determined colorimetrically as permanganate after periodate oxidation (17). In some cases 1,000 ppm. Cu^{++} or Co^{++} were added in N $Ca(NO_3)_2$ or N NH_4NO_3 after the exchangeable or after the easily reducible Mn was extracted to test for further release of manganese from the soil by heavy metals. Four washings with the N $Ca(NO_3)_2$ or N NH_4NO_3 were made. Soil samples subjected to nitric-perchloric digestion were taken up in N HNO_3, centrifuged, washed with dilute HNO_3 and the supernatant analyzed for manganese. Total Mn was measured by this procedure.

Prior to analysis, the samples were stored at their field moisture and at 5°C. The well-known increase in exchangeable Mn on air-drying of soil was confirmed and the work of Boken (2) showed that refrigeration of samples at 10°C. maintained the exchangeable Mn at the same value as fresh damp samples for a period of several weeks. A separate portion of each sample was used for determining oven-dry weight. All results are reported in this paper on the basis of ppm. Mn of oven-dry soil.

This paper deals with the manganese in soils that have received little or no manganese in addition to their native supply.

RESULTS AND DISCUSSION

Manganese usually has been found to accumulate in the upper soil horizons, according to Leeper (13). In Florida soils, previous work (5) has indicated that manganese is highest in the top 6 inches of the profile. The writer has found that both exchangeable and easily reducible Mn are several times less in the 6 to 12 inch layer than in the surface 6 inches. The exception was in profiles of Everglades peat where layers at these two depths gave about the same values. Leeper (13) concluded that the managanese accumulation uniquely paralleled organic matter accumulation, possibly as a result of roots bringing up manganese from lower depths and retention of manganese in the plant residue. Reuther and Smith (16) have found that both manganese and copper accumulate in the top 3 inches of older Florida citrus groves. They also reported a very highly significant correlation between incidence of iron chlorosis and Mn content of the grove soils. Wander (23) reported that phosphate and manganese accumulation were related in citrus soils. In this paper, the data are confined to the manganese solubility in the top 6 inches of some Florida soils.

The soils sampled in West Florida were found to have a rather high manganese status as indicated by values for easily reducible Mn in excess of 300 ppm. or the equivalent of 600 pounds per acre. These data are shown in Table 1. A significant reduction in both exchangeable Mn and and easily reducible Mn was found in soils tested three years after an application of 3,000 pounds per acre of dolomitic limestone. Crop rotation had little measurable effect on the manganese solubility in the Red Bay series sampled at Mobile Unit No. 3 in Jackson County. According to values found by Sherman et al. in Kentucky (19), the exchangeable and easily reducible Mn in these West Florida soils is more than ample for crop production. The Greenville, Red Bay, Faceville and Norfolk

soils from present data would be in this category. Total manganese was reported in a similar range for other soil types in this area (5).

TABLE 1.—MANGANESE IN SOILS FROM WEST FLORIDA STATION SHOWING THE EFFECT OF LIMING ON EXCHANGEABLE MN AND EASILY REDUCIBLE MN.*
(0"-6" Depths Sampled)

Soil Type		Soil Manganese: Exchange-able	Soil Manganese: Easily Reducible	Soil Manganese: Total	pH
		ppm Mn	ppm Mn	ppm Mn	
Greenville fine sandy loam	Unlimed	19 ± 5	424 ± 100	744	4.7
	Limed	12 ± 2	196 ± 7		5.6
Greenville-Faceville f.s.l. complex	Unlimed	19 ± 1	390 ± 35	630	4.9
	Limed	9 ± 2	360 ± 1		5.5
Faceville f.s.l.	Unlimed	7.7	195	430	4.8
	Limed	2.7	164		5.5
Ruston-Marlboro f.s.l. complex	Unlimed	7.5 ± 1.2	150 ± 8	282	4.6
	Limed	3.6 ± 1.2	103 ± 6		5.6
Norfolk f.s.l.	Unlimed	12 ± 2.2	144 ± 22	290	4.7
	Limed	7.7 ± 1.0	114 ± 4		6.1

* Analysis of variance of these data showed highly significant F value for lime depression of both exchangeable and easily reducible Mn in these soils.

Other soil types sampled in the Quincy and Live Oak areas have a lower easily reducible Mn and usually lower exchangeable Mn than those in West Florida. Table 2 shows these values. Norfolk has less easily reducible Mn in this area than those found in Santa Rosa County. The values for Lynchburg and Klej are much lower than for other soil types. Samples from plots at the Suwannee Valley Station showed a small decrease in both exchangeable Mn and easily reducible Mn where liming was at one ton per acre. The addition of cobalt to the extracting solution on the Klej soil after removal of the exchangeable Mn, released 1.5 ppm. Mn and after the easily reducible Mn, another 3.2 ppm. Mn.

Manganese solubilities in soils from Central Florida that were sampled for these studies are given in Table 3. In the Scranton sand, heavy liming decreased the exchangeable Mn from 7.5 ppm. to 2.5 ppm. and the easily reducible Mn from a value of 48 ppm. to 25 ppm., but without incidence of Mn-deficiency symptoms in tomatoes. Plot studies on Leon sand at the Beef Research Unit have not given yield response to Mn fertilization. The value reported in Table 2 from these plots show that the exchangeable Mn and easily reducible Mn are higher where 20 pounds per acre of manganous sulfate were applied than the other plots. The manganese values are higher in the 0-3 inch level than the 3-6 inch level. Liming at the 1½-ton rate and 3-ton rate had slight effect on the solubility of the manganese, although the soil pH was about 6.4 at the higher rate of liming.

These samples were taken one year after fertilization with manganese and liming. Apparently the amounts of manganese were sufficient in this Leon soil for clover and Pangola grass.

TABLE 2.—MANGANESE IN SOILS FROM NORTH FLORIDA.
(0"-6" Depths Sampled)

Soil Type	Soil Manganese			pH
	Exchangeable	Easily Reducible	Total	
	ppm Mn	ppm Mn	ppm Mn	
Jackson County				
Red Bay f.s.l.	26.0-33.0	385-395	1300	6.1
Red Bay f.s.l. level phase	25.0-30.5	820±1020	2300	5.6
Red Bay-Americus complex	6.0-9.9	295±306		5.9
Gadsden County				
Norfolk loamy fine sand	10.6-15.0	59-90		4.7-5.2
Orangeburg l.f.s.	3.8-10.7	149-169		5.2-5.8
Goldsboro l.f.s.	2.3-8.8	80-87		5.1-5.4
Lynchburg l.f.s.	3.0-3.2	4.3-5.6		4.8-5.8
Klej f.s.	4.8-5.6	26.0-31.5		5.2-5.4
Suwannee County				
Klej f.s.				
Unlimed	3.5-5.5	8.5-14.0		5.0-5.1
Limed	3.2-3.5	5.8-7.3		5.5-5.7
After above plus cobalt	1.6	3.2		

In Rutledge soil at pH 7, manganese deficiency in oats was observed; the exchangeable Mn was determined as 1.7 ppm. Fellowship loamy fine sand was found to have a much higher manganese status than the above Leon, Rutledge and Scranton soils. Ruskin sand from Hillsborough County was found to have manganese in amounts likely adequate. Soils from several fields in the Hastings area were analyzed and found to give low manganese values with little evidence of easily reducible Mn in excess of exchangeable Mn. On the only area where Mn-deficiency in crops was observed, the pH was 7.1 and the exchangeable Mn 0.9 ppm. Elsewhere, where soil pH normally is from 4.5 to 6.1 the supply of manganese must have been adequate so far as deficiency symptoms are concerned.

In the Sanford area, after many years of vegetable production, the soil manganese, Table 3, contained above 2.3 ppm., of exchangeable Mn and above 6.5 ppm. of easily reducible Mn. Everglades peat in the portion of the Apopka deposit occurring in Lake County contained from 1.8 to 3.8 ppm. of exchangeable Mn and 25 to 31 ppm. of easily reducible Mn from pastures established two years. Addition of copper in the extracting solutions released a further amount of manganese, usually 5 ppm. Since herbage from these pastures contained about 50 ppm. Mn, the supply of manganese was likely adequate.

Everglades peaty muck at pH 7, which produced manganese deficiency symptoms and low manganese content in tomato plants, was found to contain less than 0.1 ppm. of exchangeable Mn, 72 ppm. of easily reducible Mn. The addition of copper sulfate in the extracting solution released

a further 26 ppm. Mn. The total manganese was 295 ppm. Where manganese addition was made. the exchangeable Mn was not increased measurably even at rates sufficient to produce plants normal in appearance and in manganese content.

TABLE 3.—MANGANESE IN SOILS FROM CENTRAL FLORIDA.
(0"-6" Depths)

Soil Type		Soil Manganese Exchange-able	Easily Reducible	Total	pH
		ppm Mn	ppm Mn	ppm Mn	
Alachua County					
Scranton s.					
	unlimed	7.5	48	160	5.0
	limed	2.5	25		7.5
Leon s. (Beef Research Unit)					
1.5 ton lime	0"-3"		3 5	10	5.4
	3"-6"		2.5	7.1	4.4
as above + Mn*	3"-6"		6.5	13.5	5.4
	3"-6"		3.5	8.0	4.6
3 tons lime	0"-3"		2.5		6.5
	3"-6"		0.5		5.4
as above + Mn*	0"-3"		4.8		6.4
	3"-6"		3.0		5.3
Rutledge s.					
	unlimed	3.8	6.0	55	4.8
	limed**	1.7	5.5		7.0
Fellowship l.f.s.		10 0	122	185	5.5
Hillsborough County					
Ruskin f.s.		7.5	28		5.3
St. Johns County (Hastings area)					
Bladen f.s.		**0.8-2.1	2.0-3 6		4.4-6.1
Seminole County (Sanford area)					
Leon s.		2.3-10.0	6 5-45.0		4.9-5.4
Lake County (Astatula area)					
Everglades peat		1.8-3.8	25.0-30.6		5.2-6.1
after above + Cu		4 5	5.8		

* 4 pounds Mn supplied as manganous sulfate.
** Manganese deficiency in crops on this soil.

A sample of Perrine marl taken from an area which was being brought into cultivation contained 15.1 ppm. exchangeable Mn. This soil, pH 8.3, in lysimeter jars after a year of cropping, was found to have 13.6 ppm. of exchangeable Mn. Easily reducible Mn was 21 ppm. and total Mn 105 ppm. This marl produced severe symptoms of manganese deficiency in tomatoes unless manganese fertilization was made. Apparently this alkaline soil has exchangeable Mn in excess of many sandy soils in Florida. Possibly the mobility of the manganese may be the factor responsible for deficiency as has been postulated for other calcareous soils (1).

In determining the exchangeable Mn, both N $Ca(NO_3)_2$ and N NH_4NO_3 gave similar results. The latter extractant was made from redistilled

reagents to avoid the possibility of impurities such as Cu, Fe, and Zn releasing Mn by chelate interchange in the organic matter. The possibility existed that the extracting agent put into solution enough copper and /or iron from the soil to replace manganese from the organic matter. Both copper and/or iron were found in the extracting solution in amounts exceeding the exchangeable Mn. The fact that copper or cobalt addition released some manganese in addition to that extracted previously is further direct proof that manganese may have been replaceable from the soil by the action of heavy metals. In an old grove soil, Reuther and Smith (16) showed that there was more manganese accumulation down to 36 inches for each horizon than there was copper. Some replacement of manganese accumulation by copper might explain these data.

The fact that, in some Florida sand soils, manganese termed exchangeable has not been leached by heavy fertilization bears comment. It has long been a recognized fact that acid soils have a higher exchangeable Mn than less acid soils. This essentially means that this manganese was not replaceable by hydrogen ion at these soil acidities. Preferential retention of manganese in such soils as Leon which have received a ton or more of fertilizer per year, which is the equivalent of 500 ppm. of exchangeable cations, may be the answer. Conversely, enough manganese in the organics in the fertilizer, in manganese impurity in the fertilizer ingredients and in crop residues may be added yearly to compensate for leaching losses. A crop of 15 tons per acre of green weight equivalent to about 3 tons of dry matter containing 100 ppm. Mn, removes 5 ounces of manganese per acre. Crop removal itself results in a slow depletion of the native manganese.

The fact that some Florida soils contain less than 25 ppm. of easily reducible manganese, but are not manganese deficient, is of interest. In Kentucky (19) and in Australia (12) such values are found where manganese deficiency has occurred, particularly if the pH is 6.5 or above. Either manganese is kept available by different mechanisms in Florida sands than in those soils, or the manganese solubility is adequate because of the acidity of Florida soils. Those soils having high easily reducible manganese require further study to determine if the level is excessive with respect to manganese uptake and relationships to other nutrient availability. The easily reducible Mn is usually considered as the active fraction in assessing the manganese availability in soils. A portion or all of this manganese may be from surface reduction of higher oxides of manganese deposited on the surfaces of the organic and inorganic portion of the soil. Alternatively, the manganese may exist in organic combination in such a way that reduction of the organic matter releases the manganese. In most Florida soils the total manganese is several times in excess of the easily reducible fraction.

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MINOR ELEMENT CONTENT OF SOME FERTILIZER MATERIALS — PAST AND PRESENT — IN RELATION TO THE FLORIDA FERTILIZER PROGRAM

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During the period 1927 through 1932, I was employed by one of the major fertilizer companies of Florida in a research and consulting capacity for the particular purpose of studying fertilizers and fertilizer materials in relation to possible revision and improvement for agricultural use. The historical references and technical data here presented represent principally personal experience and technical data accumulated during the period of 1927 through 1935, and is presented as such.

The extent of my knowledge at that time of the use of plant foods other than the usual nitrogen, phosphoric acid, and potash in Florida fertilizer practice included only the use of copper sulphate as a cure for "die back" in citrus trees, later identified as copper deficiency; use of manganese sulphate principally on tomatoes in marl soils, following USDA work under Dr. Skinner and his finding that the principal virtue of stable manure on marl soils was due to its manganese content; and the use of other materials, such as hardwood ashes, manures, and limestone, principally high calcium limestone. These materials were used without specific knowledge, only practical observation, that they had corrective properties upon some unfavorable conditions appearing in growing plants and trees. The heavy use of organic materials in fertilizers and as direct application had been practiced for a long time, again based upon practical observation of their beneficial effects in the growing of crops, but without specific knowledge as to why such results were obtained. Hardwood ashes were in wide use and great demand as a general corrective, and gave corrective results upon many abnormal conditions, particularly on citrus trees, which did not respond to any other known treatment. It was becoming increasingly difficult to get supplies of good quality domestic hardwood ashes. Demand had increased to such a point that the greater portion of ashes obtainable were severely leached or derived from softwood, and of such inferior quality that little or no beneficial results were obtained. Importation of Canadian hardwood ashes had begun and these were found to be of the highest quality, but limited in supply in relation to demand. Realizing the need and demand for a manufactured mixture which would replace and improve upon the best quality hardwood ashes and which would be of uniform composition, many samples of the best Canadian ashes were completely analyzed and tabulated. Practically all of the commonly used fertilizer materials were also completely analyzed and tabulated.

Hardwood ashes were sold upon a guarantee of calcium equivalent to calcium carbonate, usually a minimum of 65%, and potash as K_2O guaranteed upon the percent content of each particular lot. The complete analysis developed information that ashes were very rich in content of

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such elements as iron, copper, manganese, zinc, boron, etc., in comparison with any of the other materials, and offered a solution of the very puzzling question as to why growers were willing to pay fancy prices for and import from as far as Canada, a material upon which the known rated value was based upon three quarters of a ton of cheap limestone and two or three units of potash, a combined value of about $5.00 per ton.

Following factory and mixing experiments, a basis for formulation was decided upon, and the mixture offered and sold in commercial quantities beginning in 1928. A trade name had been developed and copyrighted. The mixture was advertised and sold under this trade name as a hardwood ash substitute, later as a soil conditioner, without reference to any part of the formula other than potash. It was registered and guaranteed with the State Department as to its potash content only, since no guarantees other than primary plant foods were required at that time. This mixture met with enthusiastic reception among the customers of this particular company, and within a short period became a commercial success, with a steadily growing demand. Other fertilizer companies followed subsequently with somewhat similar formulas under various trade names. These mixtures progressively entirely replaced hardwood ashes among the customers of the companies supplying the mixtures.

The fertilizer industry and others became actively interested in pH value and relative acidity or alkalinity of soils beginning about 1930. Since hardwood ashes or equivalent mixtures could not be used on alkaline soils, experimental mixtures were designed for use on such soils. These special purpose mixtures, in addition to especially selected fertilizer materials, contained one or more of the secondary elements as carried in the hardwood ash substitute. These mixtures were registered and sold under special brand names, and were followed by other mixtures designed especially for very acid soils. Such mixtures were registered and guaranteed also in respect to primary plant foods only.

Secondary Plant Food Content of Fertilizer Materials, Period of 1927-1930.

	MgO	MnO	CuO	ZnO	Fe_2O_3	B_2O_3
Sulphate of Ammonia	0.000	0.009	0.008	0.037	0.020	0.000
Nitrate of Soda	0.120	0.009	0.003	0.000	0.000	0.110
Chilean Nitrate of Potash	0 200	0.000	0.004	0.000	0.020	0.740
Sulphate of Potash	0.150	0.005	0.034	0.000	0.230	0.000
Kainit	5.760	0.017	0.003	0.000	0.340	0.140
Milorganite	0.240	0.450	0.230	2.050	2.550	1.340
Goat Manure	1.150	0.830	0.116	0.320	3.320	1.480
Peruvian Guano	0 850	0.280	0.090	0.080	4.430	0.420
Castor Pomace	0.360	0.170	0.180	0.220	1.150	0.480
Cottonseed Meal	0.250	0.180	0.390	0.120	1.370	0.310
Animal Tankage	0 450	0.210	0.110	0.160	2.790	0.000
Bone Meal	0.940	0.220	0 034	0.082	1.930	0.230
Superphosphate	0.160	0.300	0.034	0.310	1.530	0.000
Triple Superphosphate	0.300	0.230	0.070	0.087	1.910	0.000

The Florida Agricultural Research Institute was organized in 1932, and began active operation in 1933. One of its major objectives was to coordinate, extend, and enlarge the scope of research and application

of data in reference to fertilizer mixtures and secondary elements. At that time I was instructed to transfer to the Institute all of the accumulated data, formulas, etc., for the benefit of its members and of Florida agriculture in general, and to act as consultant to the Institute for a considerable period of time. Prior to that time all of this information had been held as a trade secret. The Institute laid out and undertook field experiments upon a large and active scale, and gradually engaged in collaborative work and exchange of accumulated data with various government agencies, especially the Citrus Experiment Station at Lake Alfred. Beginning about 1935, that station engaged in an intensely active program of field experiments supported by suitably increased laboratory research and analyses which rapidly produced a great volume of added knowledge about the function and use of the individual elements and their relation to each other in citrus production. By the late 1930's and early 1940's, practically all formulation and usage of these elements in relation to citrus were based upon recommendations originating at that station. In the meantime, other agencies had followed a similar line of intensified research related to crops other than citrus, with correspondingly increased knowledge and improved recommendations.

ONE OF THE 1928 FORMULAS OF COMMERCIALLY MARKETED HARDWOOD ASH SUBSTITUTE.

High Calcium Limestone	1,350
Hydrated Lime	300
Epsom Salts (Mg Sulphate)	50
Manganese Sulphate	50
Copper Sulphate	40
Zinc Sulphate	30
Ferrous Sulphate	60
Borax	10
Sulphate of Potash	110
	2,000

It is of interest to note here that the accumulated data and experience involving secondary plant foods, in the period of 1928-1935, and the separation of total nitrogen into its four divisions, ammoniacal nitrogen, nitrate nitrogen, water-soluble organic nitrogen, and water-insoluble nitrogen, which had been studied and developed during the same period, furnished the material upon which the 1935 Fertilizer Law was written. This was the first fertilizer law ever passed which covered requirements for guarantees of secondary elements and nitrogen divisions in percentages. This law served as a model for drafting many subsequent state fertilizer laws.

Following passage of the 1935 Fertilizer Law, and publicity given findings and recommendations of the Experiment Stations, use of these secondaries, individually and in groups, in fertilizer mixtures and spray applications, became practically routine, both as to what were called corrective programs and maintenance programs, for a long period of years. This program was primarily responsible for the increased general level of secondaries which we have at present in cultivated soils. During this period, the use of natural organic materials and special soil conditioners declined rapidly, natural potash and nitrogen salts were highly purified, and manufactured sources of nitrogen, containing little if any

secondaries, became one of the principal sources of nitrogen in fertilizers. Fertilizer materials and soil conditioners lost practically all consideration as sources of secondaries other than calcium and magnesium from limestones.

Summarizing the historical and technical information which has been presented, it will be found that the secondary element content of fertilizer materials in its relation to the Florida fertilizer program, past, present, and future, may be divided roughly into four phases as follows:

1. Period prior to about 1926, during which agriculture had its supply of secondaries from fertilizer materials, hardwood ashes, manures, and limestones, in haphazard supply, and with little if any general knowledge as to their need or function.

2. Period from about 1926 to 1933, during which specific information related to the use of some single secondaries, particularly copper and manganese, as corrective under special conditions became generally known and used: comprehensive mixtures of secondaries, regulated as to uniform formulas, and special fertilizer mixtures supplemented with one or more secondaries, were commercially marketed and reached a relatively small percentage of general agriculture, the remainder being still dependent upon chance supplies from fertilizer materials, and the corrective use of hardwood ashes, etc., as formerly.

3. Period from 1933 to 1940, during which the supplying of secondaries as supplements in fertilizer mixtures and spray applications upon a calculated basis, both corrective and maintenance, came into general practice, accelerating rapidly after 1935. Foliage patterns and other symptoms indicating deficiencies of the individual elements were identified and catalogued, permitting accurate diagnosis of deficiencies and accurately calculated corrective applications.

This period was extended to about 1952, during which extension the so-called maintenance supplies of secondaries became almost routine in fertilizer applications, use of organics declined, and use of ashes, manures, soil conditioners, etc., practically disappeared. Natural salts of potash became highly purified, manufactured sources of nitrogen of almost technical purity became the principal supply of mineral nitrogen, and the use of phosphate began to decline. Fertilizer materials lost their significance as sources of secondaries, and fertilizer formulation was changed accordingly.

4. Period beginning in 1951-1952, in which the significance of the accumulated levels of secondaries in cultivated soils, particularly citrus, was realized upon an increasing scale. Supplemental use of secondaries decreased rapidly, and today is but a small percentage of the peak period, and confined almost entirely to corrective treatment and new soils. This resulted in radical changes in fertilizer formulation, with small or no consideration of secondaries in materials. The future presents a period during which we will enjoy the benefits, and suffer from some of the faults, of our accumulated high levels of secondaries in soils cultivated for long periods.

A STUDY OF MINOR ELEMENT APPLICATIONS ON WEST FLORIDA SOILS

C. E. Hutton and W. K. Robertson*

Crop responses to minor element additions have been reported on many Florida soils. These data deal with the sands of Peninsular Florida for the most part. Little or no information is available on the heavier textured soils of Western Florida.

To determine whether the yields of some of the important row- and small-grain crops could be increased by the addition of the minor or secondary elements. an experiment was initiated in the fall of 1949 at the West Florida Experiment Station.

EXPERIMENTAL 1949-53

The experiment was laid out as a complete randomized block, using a split plot technique to study the effect of dolomitic limestone. The soil on the experimental area belongs to the Red Bay series and was predominantly fine sandy loam.

Table 1 shows the treatments and rates of minor elements applied.

TABLE 1.

Treatment	Applied As	Lbs./Acre*
Copper	$CuCl_2.2H_2O$	10.0
Iron	$FeCl_2.4H_2O$	12.5
Manganese	$MnCl_2.4H_2O$	12.5
Boron	Borax	20.0
Zinc	$ZnCl_2$	12.5
Sulfur	$CaSO_4.2H_2O$	100.0
All	Same as above	Same as above
Check	None	None

* Lbs. per acre are in terms of the form listed in Column 2.

The treatments were tested on a three-year rotation, consisting of lupines to corn the first year, oats for grain followed by soybeans the second year, and oats turned to peanuts the third year. The crops were replicated so that all crops occurred in each treatment block every year. Data are presented here for corn, oats (for grain), soybeans, and peanuts. Fertilizer applications—applied to each crop every year—consisted of 100 pounds P_2O_5 from triple superphosphate, 100 pounds K_2O from

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A contribution of the West Florida Station, Jay, and the Soils Department, Main Station, Gainesville, Florida Agricultural Experiment Stations.

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muriate of potash and 80 pounds N from NH_4NO_3 except for legumes, in which case the nitrogen was reduced to 40 pounds N from NH_4NO_3 per acre. Minor element additions were made to each crop along with the major element additions, except that only N, P, and K were added in the fall of 1951 and spring of 1952. Broadcast applications of all elements were made when oats and lupine were planted. Row application was made when corn, peanuts, and soybeans were planted. Dolomitic limestone was broadcast at a rate of one ton per acre in the fall of 1949 to one-half of each plot. An additional one and one-half tons per acre of this limestone was applied in January, 1952, to the same area. Prefertilization soil samples were taken every two years from the 0-6 inch level of all plots to determine the pH range and also to decide whether phosphorus and potash level were high enough for maximum yields. The phosphorus (extractable with .03 N NH_4F in 0.1 N HCl (2)), the exchangeable potassium and the pH values from the 1953 prefertilization samples are recorded in Table 2.

TABLE 2.—Some Chemical Data* from 1953 Prefertilization Soil Samples.

Treatment†	pH		Lbs. per Acre					
			"Strong Bray" P_2O_5**			Exchangeable K_2O		
	L	UL	L	UL	Ave.	L	UL	Ave.
Cu	6.1	5.0	252	252	252	286	210	248
Fe	6.0	5.2	204	238	221	254	194	224
Mn	6.0	5.0	263	252	258	286	210	248
B	6.0	5.2	302	275	288	346	240	293
Zn	5.9	5.1	238	142	190	226	210	218
S	5.8	4.9	204	318	261	254	180	217
All	5.9	5.0	213	302	258	286	210	248
None	5.8	5.0	252	224	238	120	194	157
Average	5.9	5.0	240	250	245	257	206	232

* Values are averages of two replications.

** Phosphorus extracted with .03N NH_4F in .1 N HCl, 10-1 dilution.

† Rates of application shown in Table 1.

Data in Table 2 indicate that there is a difference of approximately one pH unit between the limed and unlimed plots. From correlation studies in the area, the levels of potassium reported appear to be high enough to eliminate it as a variable. The level of phosphorus reported was low, but probably adequate for most crops. Since phosphorus builds up, this situation was rectified after the 1953 phosphorus applications. However before the 1952, 1951 and 1950 applications, phosphorus could have limited yields. Since lime has improved the availability of soil phosphorus on corn and peanuts (5, 8) an over-all response to lime might be an indication of phosphorus deficiency. There was some indication of this in 1951 (Table 4). That the response was due to phosphorus seems most plausable since exchangeable calcium was relatively adequate, being approximately 300 pounds per acre on the unlimed soil.

TABLE 3.—RESULTS* FROM ANALYSES OF 1954 CORN EAR LEAF SAMPLES TAKEN AT TASSELLING TIME.

Treatment**	% K†			% P†			% Mg†			P.P.M. Mn‡		
	L	UL	Ave.	L	UL	Ave.	L	UL	Ave.	L	UL	Ave.
No B	2.27	2.36	2.32	0.25	0.23	0.24	0.257	0.157	0.207	137	1085	611
No Mg	2.54	2.45	2.50	0.23	0.24	0.24	0.202	0.157	0.179			
No Cu	2.31	2.26	2.28	0.25	0.24	0.24	0.203	0.117	0.160			
No Zn	2.33	2.47	2.50	0.26	0.24	0.25	0.203	0.200	0.202			
No Mn	2.48	2.29	2.39	0.25	0.25	0.25	0.257	0.107	0.182	78	699	388
No Mo	2.73	2.58	2.66	0.26	0.22	0.24	0.247	0.177	0.212			
	2.36	2.58	2.47	0.25	0.24	0.24	0.168	0.160	0.166			
Check	2.45	2.71	2.58	0.26	0.24	0.25	0.197	0.145	0.171			
Average	2.44	2.46	2.46	0.25	0.24	0.24	0.217	0.152	0.185	108	892	500

* Values reported are averages of three replications.

** Plots received: B, Mg, Cu, Zn, Mn and Mo at the rates shown in Table 1 except where otherwise stated.

† Data were non significant except the effect of lime on Mg uptake which is highly significant.

‡ Mn was determined on treatment 1 which received Mn and on treatment 5 where it was omitted.

Profile samples were taken in 1954 to determine the leachability of the various elements applied. These samples will be processed at a later date.

Leaf samples were taken at tasselling time in 1954. The treatments had been revised in the spring of 1954 so that all minor elements but the minor element tested were applied (i.e. all but Mn, all but Zn, etc.). The same plots were used as in previous years and treatments were arranged so that residual materials would not interfere. These samples were oven dried at 70°C. and ground to pass through a 2 mm. screen. A portion of the sample was wet-digested with concentrated nitric and perchloric acid (10:1 ratio) and taken to dryness. The residue was taken up in 1 N HNO_3 and filtered. The MnO_2, being insoluble in HNO_3, was left on the filter paper. The filtrate was analyzed chemically for phosphorus (7), magnesium (3), and manganese (9). Manganese was also determined on the filtrate by the above procedure. Magnesium analyses were made on the filtrate using the Beckman DU flame photometer and the hydrogen flame. The 383 millimicron wave length was used. Another portion of plant material was ignited at 450°C. for calcium and potassium determinations. These determinations were made on the Beckman B using the 622 and 768 millimicron wave lengths, respectively. (Table 3 contains a summary of these data.) The manganese values shown are an accumulation of the manganese values in the filtrate and in the precipitate determined chemically. The magnesium values reported were those obtained using the flame, since these values were preferred to those found using the chemical method.

The data in Table 3 indicate that treatments did not affect the accumulation of potassium and phosphorus in the plant material. When these values are compared with those reported by Beeson (1) it is evident that the levels of these elements are sufficient for normal growth. Liming caused a significant increase in the level of magnesium probably due to the magnesium in the dolomitic lime.

TABLE 4.—CORN YIELDS IN BUSHELS PER ACRE AS AN AVERAGE OF ALL REPLICATIONS.

Treatment	1950		1951		1953		3-Year Ave.	
	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
Cu	69	68	83	74	78	69	77	70
Fe	64	69	84	84	79	74	76	76
Mn	74	73	82	69	80	61	79	68
B	67	74	86	83	83	73	79	77
Zn	67	70	88	87	83	71	79	76
S	69	68	84	83	86	69	81	73
All	75	75	90	67	80	67	81	69
None	67	70	84	79	78	65	76	71
Treatment L.S.D. 5%	N.S.		7.7		7.7		7.7	
Treatment L.S.D. 1%	N.S.		10.7		10.7		10.7	
Lime L.S.D. 5%	6.0		6.0		6.0		6.0	
Lime L.S.D. 1%	N.S.		8.3		8.3		8.3	

TABLE 5.—Peanut Yields in Pounds per Acre As An Average of All Replications.

Treatment	1950		1951		1952		1953		4-Year Average	
	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
Cu	2110	1910	910	770	1320	1130	1170	870	1377	1170
Fe	1960	1830	770	760	1580	1260	1200	870	1377	1180
Mn	1680	1600	940	780	1520	900	1120	750	1315	1007
B	1670	1650	1000	710	1490	1090	1220	980	1345	1107
Zn	1970	1880	890	910	1170	1090	750	800	1195	1170
S	1980	1900	890	690	1530	1020	1180	890	1395	1125
All	1840	1840	850	810	1250	950	800	660	1185	1065
None	2050	1740	890	690	1520	1230	1200	840	1415	1125
Treatment L.S.D. 5%	N.S.		N.S.		N.S.		280			
Treatment L.S.D. 1%	N.S.		N.S.		N.S.		389			
Lime L.S.D. 5%	274		192		280		114			
Lime L.S.D. 1%	N.S.		261		386		157			

TABLE 6.—Oat Yields in Bushels per Acre As An Average of All Replications.

Treatment	1950		1951		1952		1953		4-Year Ave.	
	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
Cu	29.5	33.2	51.0	50.4	68.2	61.8	33.7	34.4	45.6	45 0
Fe	......	......	46.8	47.1	58.4	62.8	34.1	32.1	46 4	47.3
Mn	34.1	28.5	54.3	50.1	66.2	82.4	24.5	31.4	44.8	48.1
B	27.4	29.6	52 9	52.2	54.6	72.6	26.7	37.3	40.4	47.9
Zn	29.8	33.4	48.3	51.0	87.2	85.5	31.7	43.4	49.3	53.3
S	27.8	28.4	52.9	49.2	77.7	84.5	35.1	37.8	48.4	50.0
All	24.8	31.6	54.0	54.7	61.4	62.4	21.9	39.1	40.5	47.0
None	32.5	32.2	52.2	48.0	68.9	83.1	20.0	39.4	43.4	50.7
Treatment L.S.D. 5%	N.S.		N.S.		29.6		13.8			
Treatment L.S.D. 1%	N.S.		N.S.		N.S.		N.S.			
Lime L.S.D. 5%	6.5		N.S.		13.4		6.1			
Lime L.S.D. 1%	N.S.		N.S.		N.S.		8.4			

TABLE 7.—SOYBEAN YIELDS IN BUSHELS PER ACRE AS AN AVERAGE OF ALL REPLICATIONS.

Treatment	1950		1951		1952		1953		4-Year Ave.	
	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
Cu	19.9	15.5	11.3	12.1	22.3	14.1	28.5	27.2	20.5	17.2
Fe	18.2	18.0	11.3	8.1	26.1	15.7	28.6	25.0	21.1	16.7
Mn	21.3	17.0	9.0	7.0	24.4	7.9	30.2	26.9	21.2	14.7
B	17.3	16.8	10.1	8 3	26.3	11.9	30.4	29.3	21.0	16.6
Zn	20.8	19.7	11.3	11.3	25.2	8.2	28.5	25.4	19.0	16.2
S	20.9	19.1	11.1	8.4	21.4	9.0	30.6	27.8	21 0	16.1
All	18.8	13.8	10.1	6.1	23.3	13.3	28.5	27.7	20.2	15.2
None	20.8	15.9	10.9	8.5	20.6	11.1	30.0	27.4	20.6	15.7
Treatment L.S.D. 5%	4.8		N.S.		N.S.		N.S.			
Treatment L.S.D. 1%	N.S.		N.S.		N.S.		N.S.			
Lime L.S.D. 5%	3.1		N.S.		5.4		1.7			
Lime L.S.D. 1%	4.3		N.S.		7.5		2.4			

The annual applications of 12½ pounds of Mn $Cl_2.4H_2O$ per acre increased the Mn content of the ear leaf by approximately 57 percent. Over eight times as much Mn was taken up on the unlimed plots, indicating that lime was reducing the activity of available Mn. It has been reported (4) that the levels of exchangeable and easily reducible manganese are high in these soils. However, the manganese content of the leaves is not as high as that causing manganese toxicity symptoms in other plants (6).

TABLE 8.—OBSERVED F VALUES FROM ANALYSIS OF VARIANCE.

	1950	1951	1952	1953	1954	Combined Analysis 1950, '51, '53
Treatment						
Corn	0.65	1.33	1.03	1.35	0.45	0.73
Peanuts	0.87	0.33	1.12	2.60	......	......
Oats	1.40	0.21	1.21	0.66	0.71	......
Soybeans	1.40	0.87	0.86	0.70	......	......
Lime						
Corn	2.02	16.42**	6.86*	18.31**	16.80**	6.75*
Peanuts	2.93	7.87*	26.08**	88.64**	......	......
Oats	0.16	0.37	4.94*	33.97**	24.68**	......
Soybeans	13.50**	2.65	91.64**	33.40**	......	......
Lime X Treatment						
Corn	0.70	2.13	0.98	0.32	1.96	2.05
Peanuts	0.32	0.72	0.72	3.65**	......	......
Oats	0.81	0.21	0.80	3.57**	0.98	......
Soybeans	0.91	0.23	0.85	0.96	......	......

* Significant at 5% level.

** Significant at 1% level.

Tables 4, 5, 6, and 7 show data for corn, peanuts, oats, and soybeans, respectively, expressed as average yields for each treatment for the 1949-53 period. Table 8 presents observed F values obtained from the analysis of variance of each year's data for each crop. None of the F values were significant for treatment effect for any crop. However, the least significant mean difference was calculated because there was visible evidence of a serious nutrient disorder on the plants on unlimed corn plots every

year except 1950. The condition was more pronounced where manganese or all of the minor elements had been applied. The plant symptoms were unlike any known to have been reported in the literature. It occurred on the corn plants in May, starting as a yellowing of the new growth and progressed to cause an irregular necrotic striation effect in the same leaves. The affected plants were stunted in growth and tasselling was delayed. The plants appeared healthy again in late May or early June, and matured normally.

THE EFFECT OF TREATMENT ON YIELD

Even though F values for treatment differences obtained by means of an analysis of variance were not significant at the 5 percent level, there were some treatment differences which approached significance. Since a part of such a difference may be due to random variation in the samples, only a general discussion will be given here.

Corn.—There was no effect of minor element addition upon yield in any year on plots where dolomitic limestone was applied (Table 1). The following discussion will deal with treatment effect on unlimed plots.

In 1950, treatments had no effect on yield. In 1951, plots which received Mn or all of the minor elements had lower yields than most of the other treatments. The 1952 yields are not reported because they were limited by lack of moisture. In 1953, the Mn treatment again gave lower yields than several of the other treatments. When a combined analysis for 1950, 1951 and 1953 was run (Table 8), the Mn and "all" treatments had the lowest yields.

The reduced yield for manganese on the unlimed plots below that on the limed plots was associated with high levels of manganese in the soil (4) and plant material (Table 3). Addition of lime decreased the available manganese (4) and the manganese uptake in the corn plant (Table 3).

Peanuts.—There was no evidence of a plant nutrient disorder on peanuts except in 1953 on an unlimed plot, which received all of the minor elements. Most of the plants died on this one replicate. This appeared to be associated with soil type, since Norfolk fine sandy loam merged into the area involved. The Zn treatment on limed plots also gave a lower yield in 1953 than several other treatments.

Where soybeans and oats were used as indicator crops, there was little evidence of treatment effect at either level.

THE EFFECT OF DOLOMITIC LIMESTONE ON YIELD

Generally speaking, there was a beneficial effect of limestone addition on the yields of corn, peanuts, and soybeans, but a detrimental effect on the yield of oats, particularly when two and one-half tons per acre had been applied.

For corn there was a beneficial effect, as an average of the three years reported, when Cu, Mn, S, and all of the minor elements were applied. There was a tendency for all of the limed plots to give higher average yields than similarly treated unlimed plots. Yield increases for limestone were larger in 1953 when two and one-half tons per acre had been applied. This is in line with the previous results (5, 8) where an increase of two

bushels per acre was obtained for one ton of limestone per acre and a six to eight bushel increase for three tons per acre.

Peanut yields were increased on limed plots where no minor elements were added. Where B was added, there was an increase for lime three out of four years. Where Fe, Mn, S, and all of the minor elements were added, there was an increase in two of the four years. Where Cu was added, there was an increase only in 1953. Where Zn was added, lime gave no increase any year.

Soybeans showed yield increases to lime additions for some treatments except in 1951 when yields were low due to moisture conditions. In 1952, all of the treatments showed increased yields, in 1950 there were increases where Cu, Mn, all and none were applied and in 1953 where Fe, Mn, Zn, and none were applied.

Oat yields were decreased by the addition of limestone for some treatments. This was particularly true in the 1952 and 1953 seasons when two and one-half tons of limestone per acre had been applied. Yield decreases on limed plots were most evident where Mn, B, Zn, all and none of the minor elements were applied.

SUMMARY

An experiment was carried out to study the effect of additions of copper, manganese, zinc, boron, sulfur and iron on a three-year rotation, consisting of lupines to corn the first year, oats for grain followed by soybeans the second year and oats turned to peanuts the third year. A split plot technique was used to study the effect of dolomitic limestone. Ample applications of the major elements were made to each crop.

Minor elements did not increase significantly the yield of any of the crops tested. However, corn yields were reduced on unlimed plots where manganese and all the minor elements were added. Soil and plant-tissue tests showed that manganese activity was greatly reduced where limestone had been applied.

There was a beneficial effect from the limestone addition on corn, peanuts and soybeans and a detrimental effect on oat yields.

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SYMPOSIUM: CHEMICAL WEED CONTROL

WEED CONTROL IN STRAWBERRIES

A. N. Brooks *

Before considering any program of weed control for a certain crop it is necessary to consider just what the problem is and what methods have been and are being used to control weeds. In strawberry culture there are two periods when weed control is laborious and expensive: (1) in the nursery fields when plant beds are full of plants and weeding must be done by hand-pulling of weeds. (2) in the fruiting fields when it is necessary to hoe weeds in the plant row and pick out weeds which are too near the plants for hoeing. Most of the remainder of weed elimination can readily be accomplished by tractor cultivation. Cost of hand weeding in nursery beds varies considerably depending upon whether new land or old land is used. The cost is least for new land nurseries. Hoeing costs in the fruiting fields approximate $100 per acre. which is 20 percent of the total cost of production.

There are certain cultural practices which tend to decrease weed populations in fields and in some cases have eliminated certain species of weed plants entirely. Much has been accomplished along this line at the Strawberry Laboratory by the use of cover crops, of which velvet beans prove best for summer cover and blue lupine for winter cover. Each of these crops have been drilled in 20 or 40-inch rows and cultivated as long as possible to keep down weed growth. In this way established populations of spiny amaranth (*Amaranthus spinosus* L.), coffee weed (*Cassia tora* L.), and lamb's quarters (*Chenopodium album* L.), have been practically eliminated from the fields so treated. Another factor in weed control is the preparation of land sufficiently far in advance of bedding so that one or two extra diskings to destroy germinating weed seed and young weeds can be accomplished.

One material has been given a thorough testing for chemical weed control both in the nursery field and in the fruiting field. It is Crag Herbicide No. 1 (sodium 2,4-dichlorophenoxyethyl sulfate, 90% by wt.).

1.—Nursery Field in Spring and Summer of 1952

The material at the rate of 2 and 4 pounds per acre-area was applied in solution by means of a sprinkling can to plots constituting half the nursery area. The 2-lb. rate did not noticeably affect the growth of well-rooted plants where the 4-lb. rate did cause noticeable stunting of such plants. Both rates so affected the upper soil layer that it was impossible for runner plants to pin down. The young developing root tips burned off when they came in contact with the treated soil. This deleterious effect lasted for approximately two weeks, by which time weeds were starting some growth so that another application of Crag was

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necessary. Hoeing and weeding time of treated beds was 40 percent less than required for untreated beds. However, significantly fewer plants were produced on treated than on untreated beds, so much so that this treatment cannot be recommended for use in strawberry nurseries.

2.—Field of Fruiting Plants in 1952-53

In the fall of 1952 the material was applied in solution by sprinkling can to beds of well established plants at the 2-lb. rate, on each side of the rows of plants but not on the plants. Weed growth in this field was insufficient to secure significant weed counts in treated and untreated areas. There were no significant differences in yield of fruit.

3.—Field of Fruiting Plants in 1953-54

In the fall of 1953 a 4½-acre field was divided into 4-bed plots. Half of the plots were treated with Crag and half not treated. The solution was applied by means of a power sprayer, 80-100 lbs. pressure, in 12-inch bands centered on the plant row, at the 2-lb. rate. Due to extremely wet weather the first application could not be applied until December 1, by which time the plants were well established. The field had been hoed free of weeds just prior to the application of Crag.

Sixteen days after application sample weed counts were made in ten treated plots and ten untreated plots. The average number of weeds per square foot for treated plots was 2.3 weeds and for untreated plots 17.6 weeds with an L.S.D. 8.58 weeds at the 1% point. Thirty-six days after treatment and just before the second application of Crag, a similar count gave 13.0 weeds for treated and 30.9 weeds or untreated plots with an L.S.D. 13.0 weeds at the 5% point.

A record was kept of hoeing time for the 2¼ acres of treated plots and the 2¼ acres of untreated plots. There was a reduction of 18 percent in hoeing time due to treatment. Plant growth in the treatment plots was just noticeably less than in the non-treated plots. Fruit from treated plots contained more malformed fruit than from untreated plots, however, no actual counts were made. Fruit yield records from ten treated and ten untreated plots showed significantly less fruit from the treated plots; 25 quarts - 22 quarts with an L.S.D. 2.3 quarts at the 1% point. Total yield for all untreated plots was 601 quarts and for all treated plots 514 quarts for seven pickings.

4.—Field of Fruiting Plants in 1954-55

During the present season Crag was tried as a pre-setting treatment. Just before plants were set, Crag was applied at the 2-lb. rate in a 12-inch band down the center of the bed. Plants set were short-rooted and hence dependent upon the production of new roots in the soil near the surface. Weather after setting was extremely dry with constant winds both day and night. This experiment is being conducted on two phases of Scanton fine sand, a heavy and a light phase. On the heavy phase 176 percent more plants died due to treatment whereas on the light phase 800 percent more plants died due to treatment.

Crag is being applied every three weeks and none of the beds have been hoed since the plants were set. The treated beds are practically

free of weeds while the untreated beds have abundant weed growth on the heavy phase of soil and much less weed growth on the lighter phase in the field where cultural practices have greatly reduced the weed population.

From experiments and observations thus far it may be concluded that Crag affects root development in the surface layer of soil. Germinating seed in this area are killed. It has no effect upon dormant seed. Any plants with roots extending below this area are likely to survive, although in some cases they may be stunted. Strawberry plants put out new roots near the soil surface and hence will be affected to some extent by the Crag treatment. If, because of extremely wet soil or because of short roots on plants at setting time they are dependent upon this new root development near the soil surface for continued growth or even survival, it is unwise to use the Crag treatment. On the other hand, if ideal conditions for growth prevail, Crag might be used without serious effect to plants and thereby reduce the amount of labor required for weeding the plant rows. Tractor cultivation takes care of the weeds in the remaining areas of the field.

HERBICIDAL CONTROL OF WEEDS IN SUGAR CANE GROWING IN MUCK SOIL

V. L. Guzman *

Results of experiments in mineral soils have shown an increase in yield of sugar cane, in most cases, when Johnson grass (*Sorgum halepense* (L.) Pers.) and other weeds were controlled (1, 3, 4, 5). Sodium trichloroacetate (TCA), 2,4-dichlorophenoxyacetic acid (2,4-D), 3-(p-chlorophenyl)-1, 1-dimethylurea (CMU), and a mixture of TCA and 2,4-D were employed. Effective control of the grass was obtained with TCA alone or in combination with 2,4-D. The plots in these experiments varied in size from 0.4 to 4.0 acres.

In experiments conducted in organic soils (2), it was found that 2,4-D alone or better yet in combination with TCA, and CMU plus TCA, gave the best control of weeds with little or no apparent damage to the sugar cane plant. Because of the success of these small scale experiments it was desirable to test the validity of the results in an experiment of commercial size.

PROCEDURE

Sugar cane variety 223 was planted on October 30, 1952 in muck soil. At the time the experiment was established on January 28, 1953, the experimental field had been cultivated five times by using a light disc in the middles and a mechanical scratcher in the drill. The predominant weed was Alexander grass (*Brachiaria plantaginea* (Link) Hitchc.) mixed with relatively few broad-leaf weeds.

Herbicides were applied with a three-row high-clearance spray rig, equipped with a 15-foot boom. 130 gallons of solution per acre were sprayed at 50 p.s.i. pressure. Each plot consisted of 12 rows 644 feet long and 5 feet apart (an approximate area of 0.8 acre per plot). There were six treatments replicated four times. Herbicides were applied two or three times, depending upon the degree of control, and the original dosages modified when necessary to accomplish commercial control of weeds. Treatments 1 and 2, for instance, were the sodium and the amine salt of 2,4-D respectively, but the control of grasses, even when applied at a very early stage of growth, was not satisfactory. For the second and third applications, therefore, the 2,4-D salts were applied in combination with TCA. Table 1 gives the total amount of chemicals applied at each treatment. It was necessary to repeat the treatments frequently—three applications in a two month period—due to the germination of a large amount of weed seed induced by high temperatures and frequent rains. The first application was made January 28, 1953, and the last on March 26, 1953. The area sprayed was 2.5 feet wide in the drill, leaving 2.5 feet unsprayed in the middles which were cultivated. The check plots were mechanically scratched and hand hoed in the row and mechanically disced in the middles.

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The experiment was carried out on land that had previously been devoted to vegetables. During the summer months, following harvest of the vegetable crops, Alexander grass and other weeds grew profusely and the soil was badly infested by seeds of the grass. When the rains started, the large number of germinating seeds made it necessary to cultivate 23 times in order to keep the check plots clean.

TABLE 1.—TOTAL POUNDS OF CHEMICALS PER ACRE APPLIED FROM JANUARY 28 TO MARCH 26. FOR THE CONTROL OF ALEXANDER GRASS.

Treatment No.	2,4-D*		TCA**	CMU**	Approximate Cost
	Na Salt	Amine			
1	18.3	—	41.9	—	$30.26
2	—	4.5	41.9	—	21.45
3	12.5	—	41.9	—	26.00
4	—	5.2	41.9	—	22.32
5	—	—	41.9	21.2	81.05
6 Cultivated	—	—	—	—	34.35

* Pounds of acid per acre.

** Pounds of commercial grade.

Results were evaluated by the reaction of the cane plants to the chemical treatments, by height of the cane, number of shoots, control of weeds and yields of cane and sugar.

Measurement and number of cane shoots were obtained in ten plants per plot, taken at random. Five square feet were taken at random for counts and weights of weeds in each plot. The cane was harvested after burning the leaves, and as soon as feasible for commercial operation the cane of each plot was loaded separately in railroad cars and upon arrival at the mill was weighed, processed, and analyses of the juice were obtained.

RESULTS AND DISCUSSION

Neither the sodium nor amine salt of 2,4-D caused visible damage to the sugar cane plants. Temporary burning of the cane leaves occurred with TCA plus 2,4-D and TCA plus CMU. TCA plus 2,4-D damage appeared a few days after treatment as a yellowish condition which became more acute in about seven days. Depending upon the weather, recovery took place within two to three weeks. CMU plus TCA damage was manifested also by a yellowish condition and tip burning of the leaves (Fig. 1). Recovery from this condition occurred in about a month.

Table 2 presents data on the effect of each chemical on the weeds (mostly Alexander grass). The variation in number of weeds within treatments was quite large and the analysis of variance shows no significant difference in the number of weeds due to treatment. However, differ-

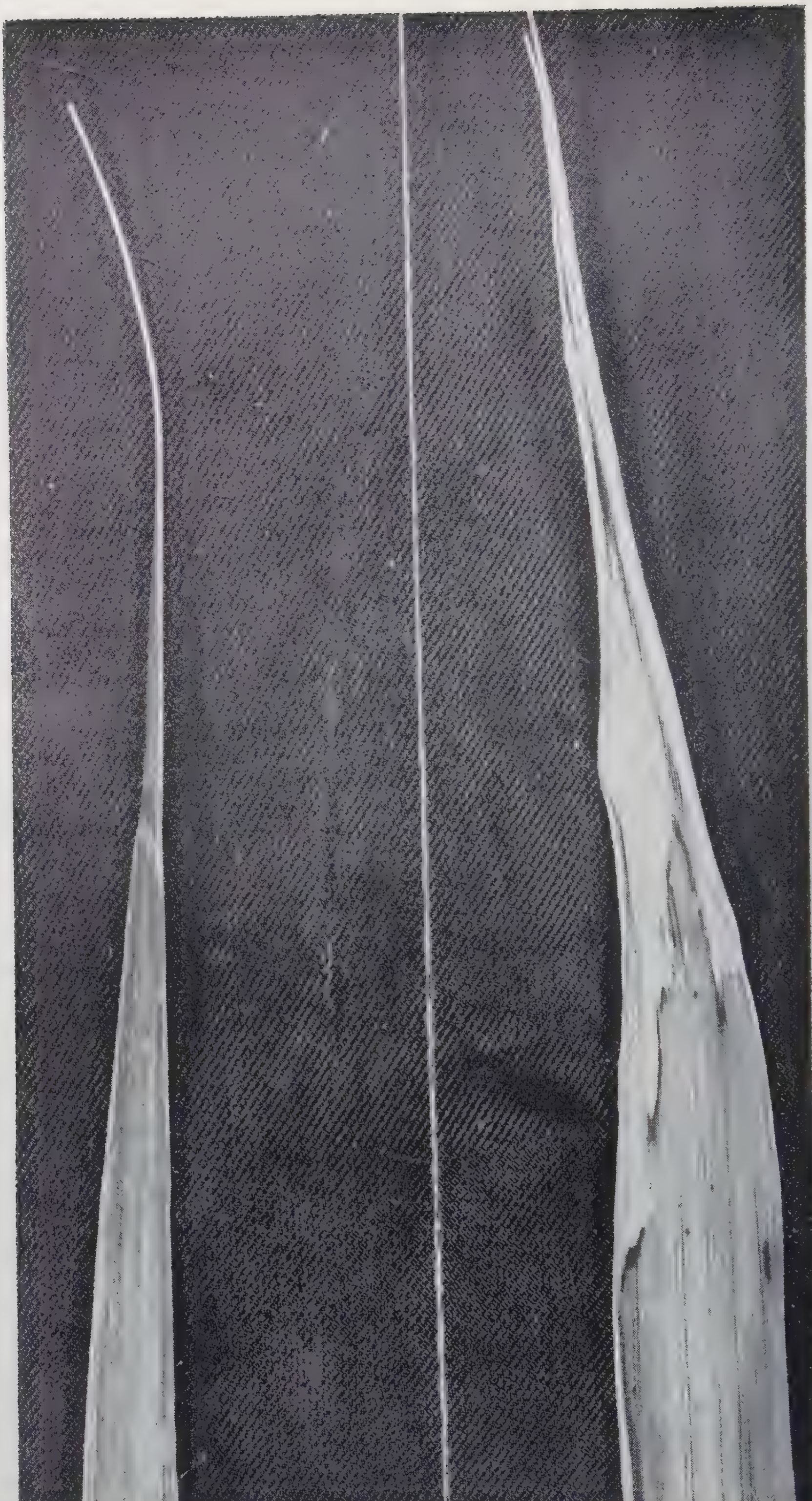

Figure 1.—Herbicidal treatment with CMU and TCA produced tip burning of the cane leaf on the right. The leaf on the left is normal.

ences in weed control were conspicuous to the eye. The cleanest plot was the check, followed by CMU plus TCA (No. 5). In this particular instance, weed counts as a measure of control gave a false idea of efficiency of each herbicide. Random samples of weeds also created a variability within treatments great enough to upset significance: for instance, treatment five (CMU plus TCA—with a total of 170 weeds), was not significantly better than treatment six (the check—with 720 weeds). The weed counts were made five days after the check plots were cultivated. Although the check plots appeared to be clean, there was a large number of very small weeds evident within five days. These weeds did not attain large size, because they were killed by the next cultivation.

Figure 2.—The sugar cane plants in plot 6 were stunted by mechanical weeding. Plants in plot 5, chemically weeded with a combination of CMU and TCA, appeared normal.

It appears difficult to measure herbicide efficiency by weed count. In this particular case the weight of weeds, or better yet, the "factor" (square root of the product of number of weeds by their weight) seems to give a better idea of weed control due to herbicidal treatments. Control of weeds measured by the "factor" is significantly better in the check (No. 6) than with CMU plus TCA (No. 5), and in the latter better than in the other herbicidal treatments (Table 2).

Table 3 gives the average length of shoots in centimeters and the number of shoots on 10 sugar cane plants per plot. Sugar cane plants in the check plots had a significantly greater number of shoots than the plants in the herbicide treated plots. This is interpreted as effect of mechanical cultivation destroying the apical dominance of the sugar cane shoot. Scratching in the drill always produces breakage of shoots and in most cases the larger shoots are broken off more easily. This condition appears to bring about development of secondary buds. The height of

shoots of the sugar cane plants in the cultivated plots were significantly shorter than in the herbicide treated plots (Fig. 2), especially during early stages of growth. Three months before harvest the differences in size had disappeared. In other words, the cane plants from the cultivated plots had apparently recovered from the stunting effect of excessive number of cultivations. The differences in height and number of shoots between herbicide treated plots were not significant.

TABLE 2.—Relative Efficiency of Herbicides Measured by Their Effect on Number of Weeds, Weight of Weeds, and the Square Root of Their Number x Weight ("Factor").

Type of Measurement	Treatments						
	1	2	3	4	5	(Check) 6	LSD .05
Number	276	372	320	452	170	720	NS
Weight	482	1972	1762	246	441	132	199.4
Factor	339	756	432	365	244	169	70.2

TABLE 3.—Average Number and Height of Shoots in Centimeters, of Ten Sugar Cane Plants in Relation to the Herbicidal Treatments Taken on June 4, 1953, About Seven Months After Planting and Two Months After the Last Herbicidal Application.

Shoots	Treatments						
	1	2	3	4	5	(Check) 6	LSD .05
Height	5186	5628	5542	4830	4513	2784	1164
Number	98	106	105	97	101	129	20

TABLE 4.—Yield in Tons per Acre of Cane, 96° Sugar, and Sugar Yield Percent Cane and Purity in Percentage Taken on January 30, 1954, One Year After the First Herbicidal Application.

Yields	Treatments						
	1	2	3	4	5	(Check) 6	LSD .05
Cane	39.60	43.42	41.29	34.04	39.12	36 03	2.88
96° Sugar	4.49	4.93	4.66	3.82	4.61	4.28	0.30
Sugar Yield	11.34	11.35	11.27	11.23	11.77	11.79	NS
Purity, %	88.10	88.85	88 45	88.52	89.20	88.89	NS

Table 4 presents yields of cane, yields of 96° sugar, sugar yield percent cane and percentage of purity. The data for cane yields in tons per acre show that the check plots produced significantly less than the herbicidal plots except for treatment 4 (2,4-D amine plus TCA). Furthermore, treatment 4 showed a significant reduction in cane yield from the rest of the herbicide plots and also a significant decrement in 96° sugar from the other treatments. It is not clear why 2,4-D amine plus TCA (treatment 4) should produce reduction in yield when treatment 2, similar in kind and amounts of the chemicals (2,4-D amine plus TCA—see Table 1), gave the best yields. There were, however, some accountable differences. Treatment 2 received only 2,4-D on the first application, while treatment 4 received at the same time 2,4-D and TCA. Later the case was reversed. The amounts of chemicals for treatments 2 and 4 varied only slightly in the 2,4-D content. Treatment 4 was also accidentally scratched in the row a few weeks after the TCA plus 2,4-D treatment was applied. It is possible that scratching placed the herbicide in contact with the roots and produced some damage to the cane plants. Sugar yield in percent cane and purity due to treatments were not significant.

Accumulation of CMU in muck soil could be possible due to the low solubility of the chemical or due to lack of decomposition of the chemical. Therefore CMU analyses were made on soil samples taken at different depths, one year after application of the chemicals (Table 5). Only 11.51 percent of the amount applied remained in the soil. The CMU concentration rapidly decreased from 1.95 pounds per acre at 0-4 inch depth to 0.02 pounds per acre at 8-12 inch depth in a one year period. The total amount of CMU left in the soil is 2.44 pounds per acre. Indications are that this amount will not be toxic to the sugar cane plants. Furthermore, experiments now in progress indicate that for general weed control, 2-3 pounds of CMU per acre may be sufficient in most cases, especially if used in combination with 2 pounds of 2,4-D. It is possible that the residue left in the soil by application of 2-3 pounds of CMU will be negligible so far as toxic effect on the sugar plant is concerned. It should be pointed out also that the initial toxic effect of CMU manifested by tip burning of the cane leaves disappeared within a few weeks after application. Residue analysis showed no CMU in the bottom portion of the cane stalk, whereas the CMU content of the cane top portion was 0.031 ppm. This amount seems to be within the limits of tolerance.

As a matter of interest, shoot height and number and yields of the cultivated check plot were compared with those of a series of preliminary experiments conducted about the same time in four acres on the south side of the same field. The various kinds of herbicidal treatments of the experiments had different effects on weed population. The only thing they had in common was that they were never cultivated in the drills. Table 6 shows that there is a marked tendency for better yields with the herbicidal treatments in comparison with the cultivated check plot. This comparison should be taken with due reserve since no statistical evaluation was possible.

Table 7 shows the monetary gross and net returns in comparison with the check. Treatments 1, 2 and 3 showed a sizable profit. Treatments 4 and 5 showed a loss.

TABLE 5.—CMU Residue Analysis* in Muck Soil of the Florida Everglades One Year After Initial Application in Composite Samples from Four Replicated Plots Which Received a Total of 21.2 Pounds of CMU per Acre.

Depth of Sample in Iuches	CMU Residue, Lbs./A.
0-4	1.95
4-8	0.47
8-12	0.02
0-12	2.44

* Analysis performed by the Grasselli Chemicals, E. I. duPont de Nemours & Company.

TABLE 6.—Yield of Cane, Number and Height of Shoots, in Plots Chemically Treated for Weed Control in Comparison with Mechanically Cultivated Check Plots.

	Means of Controlling Weeds	
	Chemically	Cultivated Mechanically
Cane Yields in Tons per Acre	47.71	36.03
Shoot Height in Cm.	4623	2783
Shoot Number	103	129

TABLE 7.—Approximate Monetary Returns as a Result of Different Herbicidal Treatments for the Control of Weeds as Compared with Cultivated and Hand Hoed Check Plots.

Return per Acre	Treatments					
	1	2	3	4	5	(Check) 6
Cane, Tons	39.6	43.42	41.29	34.04	39.12	36.03
Value ($8.00/ton)	316.80	347.36	330.32	272.32	312.96	288 24
Cost of Weed Control	30.26	21.45	26.00	22.32	81.05	34.35
Gross Return in $	286.54	325.91	304.32	250.00	231.91	253.89
Gain Over Check	32.65	72.02	50.43	—3.89*	—21.98*	

* Loss.

The results of this experiment seem to indicate that chemical control of weeds is possible and economically profitable due to increased yield of sugar cane in some of the herbicide treated plots in comparison with the mechanically cultivated and hand hoed check plots.

SUMMARY

The effect of various mixtures of herbicides was compared with that of mechanical cultivation on sugar cane growing in muck soil in a commercial size experiment. Best control of weeds (mostly grasses) was obtained by mechanical cultivation, followed by the combination of CMU and TCA. A mixture of TCA and 2,4-D also gave commercial control of weeds; furthermore, in most cases sugar cane yields were increased over the cultivated check plots.

ACKNOWLEDGMENTS

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REVIEW OF METHODS AND FORMULATIONS FOR AQUATIC WEED CONTROL

JOHN C. STEPHENS *

I.

The general characteristics of the principal aquatic plants for this area, according to habitat, are:

(A) "FLOATERS".—Normally free floating and move with the surface current. Examples: Water hyacinths (*Eichhornia crassipes*), Water lettuce (*Pistia stratiotes*), Frogbit (*Limnobium spongia*), Floating fern (*Ceratopteris pteridoides*), Duck weeds (*Lemna* spp.), Green algae (*Chlorophyceae* spp.), Blue-green algae (*Cyanophyceae* spp.).

(B) "SUBMERGED AQUATICS".—Submersed plants that generally wave in the current as "mossy" streamers. May be either free floating or anchored. Examples: Bladderworts (*Utricularia* spp.), Coontail (*Ceratophyllum demersum*), Muskgrasses (*Chara* spp.), Naiad (*Najas Guadalupensis*), Pondweeds (*Potamogeton* spp.), Wildcelery (*Vallisneria spiralis*).

(C) "EMERGED AQUATICS".—Generally rooted in moist to flooded soil and which spread from the banks of streams and ponds or emerge above water surface from the bottom. Examples: Para grass (*Panicum purpurascens*), Maidencane (*Panicum hemitomon*), Fall panic grass (*Panicum dichotomiflorum*), Switch grass and Swamp grass (*Panicum* spp.), Creeping paspalum (*Paspalum repens*), Fort Thompson or Knotgrass (*Paspalum distichum*), Watergrass (*Hydrochloa* sp.), Pennywort (*Hydrocotyle* spp.), Alligator weed (*Achyranthes philoxeroides*), Smartweed (*Polygonum* spp.), Spatterdock or Yellow pondlily (*Nymphaea macrophylla*), White and Banana waterlilies (*Castalia* spp.), Watershield (*Brasenia schreberi*), Parrot's feather (*Myriophyllum proserpinacoides*), Pickerelweed (*Pontederia lanceolata*), Sawgrass (*Cladium jamaicense*), Spikerush (*Eleochoris* spp.), Swamp bulrush (*Scirpus etuberculatus*), Cattail (*Typha* spp.).

II.

The following methods, or combinations of them, are used in control of aquatic and marsh weeds:

(A) NATURAL CONTROL METHODS.—Modification of existing water levels and kindred changes, such as drainage and flooding. Drainage may be temporary or complete. Flooding will often drown out certain obnoxious plants. The use of dikes and dams with gates may be required, and this is often the most practical method. Control by excluding light may sometimes be effective. This may be accomplished by proper design depths for construction of new canals or reservoirs. Also, shading or

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increasing turbidity may succeed in limited areas. Changing the pH and/or mineral content of the water by introduction or exclusion of tidal water, or by supplying artesian water has been used successfully in altering ecologic conditions suitable for introduction of more desirable plants.

(B) Control Using Manual Labor.—Useful primarily for small ponds or ditches, and for maintenance to prevent reinfestation of noxious plants. Use of hand sickle or machete to cut weeds. Use of forks, rakes, or nets to gather and remove "floaters". Hand operated underwater saws are used to control certain rooted aquatic plants. Fexible double-tooth narrow banded saws are on the market which may be secured in short lengths and fastened together in lengths up to 100 feet. These should be weighted every 5 or 10 ft. to conform to bottom contour. Hand rakes to clean trash racks at pump and spillways are common. Burning is often helpful, especially when combined with subsequent flooding.

(C) Mechanical Means of Control.—These methods may involve use of draglines; chain or cable dragging using tractors, boats or amphibious vehicles; aquatic and marsh mowing machines; floating rakes, automatic lifting rakes at trash racks; crushing devices and plows. Draglines fitted with cleanout buckets are in common use for cleaning drainage canals. In addition to clearing away weed growth, silt and sandbars are removed to increase channel efficiency. This method is expensive, and plant re-growth is rapid in most cases. Chain or cable dragging is used to clear "sinkers" and shallow rooted "emergers". Under favorable conditions, this is often the most economical method, but regrowth is rapid and disposal of plants may be a problem. A few mechanical "hyacinth destroyers" are still in operation for combating "floaters" but have been largely superseded by chemical control. Underwater mowing machines, now on the market, attached to shallow draft boats can mow at depths down to 4 or 5 ft. Side-bar sickle mowers, operating off the "hydraulic" of farm tractors, capable of cutting at an angle of 45° below horizontal offer a cheap means of maintaining ditch banks and pond margins where they can operate. Mowers and cleated crushers can be adapted to light weight "Glades buggies" and used to keep down growths of reeds, cattails, sawgrass and other undesirable plants under semi-aquatic conditions. In rice fields or land planted for wildlife feeding grounds, aquatic weeds are controlled by cultivation and crop rotation.

(D) Herbicidal or Chemical Control Methods.—Recent developments in organic herbicides open new possibilities for aquatic weed control, and the use of herbicides is now the fashion. These agents promise to be most useful tools in the hands of experienced operators; however, their use may involve certain hazards to adjacent field crops, to game and aquatic life, and to man. Therefore, one should learn the proper use, the limitations, and the possible hazards before applying chemical agents. ALWAYS READ and HEED the instructions on the labels. They are there for the APPLICATOR'S protection.

Herbicidal agents may be classed into three general groups with some agents overlapping into two or more groups. These are: 1. Contact killers; 2. Soil sterilants; and 3. Systemic herbicides.

Adjuvants are often added to modify the physical characteristics and increase the killing power of herbicides such as wetting or spreading

agents, stickers, penetrants or emulsifiers. Also, two or more herbicides may be used together so as to increase the number of species that can be effectively controlled.

The CONTACT HERBICIDES are compounds which "burn off" all above-ground growth simply by destroying the plant cells with which they come in contact. They may be used on "bankers" and "emergers" above the water surface. Annuals and some shallow rooted perennials are killed, but hardy perennials are only set-back temporarily. Contact sprays may be of value in weakening the more hardy plants prior to the application of a soil sterilant, but should not usually be used before applying a translocated type of weed killer. Examples of contact killers are: aromatic oils, oils with added pentachlorophenol, dinitro formulations, and potassium cyanate. Solutions of a number of salts, including sodium arsenite, sodium chlorate, ammonium sulfamate and ammonium trichloroacetate may be used as general contact sprays, but these primarily act as soil sterilants.

For "sinkers" which are submerged, such as the naiad and coontail "mosses", aromatic solvents, or gasoline, and polychlorobenzene, orthodichlorobenzene, and 1,2,4-trichlorobenzene, or a blend of the solvents plus any of these chlorinated benzenes are effective killers when emulsifiable and injected into the water under pressure. Under Florida conditions concentrations of from 100 to 400 p.p.m. are required depending upon the type plant and contact time. In tests made at Plantation Field Laboratory the named products, of technical grade purity, were not harmful to young corn, snap beans, and tomatoes when the plants were continuously sub-irrigated for one week with these herbicides at 200 p.p.m. Two corralled steers showed no abnormal condition from drinking water treated with the same products at 600 p.p.m. in an 8 weeks test. However both animals disliked the treated water and reduced their intake to about 1 or 2 gallons per animal per day, and it was evident that had uncontaminated water been available the animals would have drunk this in preference to the treated supply. These products are fatal to fish, snails, and most other higher forms of aquatic life. Their use as flukeocides is under investigation.

For algaecides, copper sulphate in weak solutions has been used but is very toxic to fish if used in excessive amounts. Rosine Amine D Acetate or RADA has also been used as a fresh water algaecide in concentrations of from 2 to 10 p.p.m.

The SOIL STERILANTS are herbicides which may be applied either as aqueous sprays or in the powdered form. They act to kill the root system of the plants and render the soil impotent. Some agents produce a relatively temporary, and others a much longer sterility, the effect depending upon the inherent toxicity of the chemical, absorption of the chemical by the soil, decomposition tending to reduce toxicity, chemical solubility and leaching effect, soil fertility and species tolerance. Ordinarily the temporary sterilants are used for controlling perennials on crop lands, and the more permanent for clearing firebreaks, ditchbanks, fence lines and roadsides. They are usually ineffective when the plant roots are covered with standing water and their use is largely limited to the margins of streams and pond areas where the water table drops below ground level.

For south Florida a pre-weakening method has been developed recently which promises to reduce the expense of using soil sterilants. This method consists of weakening the plant by first treating it with a contact herbicide, or applying a light application of a soil sterilant followed with a fairly small dose of an agent such as TCA, polyborchlorate, or CMU from three to six weeks later. Small repeated applications have proven more effective on perennial emergent aquatics than one original heavy application.

Examples of the more widely used sterilants and some of their characteristics are:

Arsenic trioxide and sodium arsenite are very effective on shallow rooted plants but less on deep rooted perennials. Arsenic trioxide is only slightly soluble and is ordinarily applied dry. It is not highly effective the first year, but thereafter is more potent than sodium arsenite, and has a longer residual effect than the latter. Sodium arsenite prepared by mixing arsenic trioxide, sodium hydroxide, and water in the ratio of 4:1:3 by weight is very soluble and is usually applied in a water solution. Its toxic action is rapid as compared to arsenic trioxide. Both are highly residual. They are deadly internal poisons and also skin irritants and all precautions should be exercised in their use. General application rate is 600 to 1,200 lbs./acre.

Sodium chlorate applied to the soil is very poisonous to both annuals and perennials. It is quite soluble and readily leached. Better kill is obtained when rain follows treatment. The rate required depends on plant species and rainfall. It is highly inflammable when mixed with organic matter, and clothing wet with chlorate is almost explosive when dry and may be readily ignited by flame or friction spark. Not to be used during hot, dry weather, or sprayed onto finely divided acid organic matter, such as decaying leaf mold. No smoking around chlorates or when they have been recently applied. Average requirement is 100 lbs./acre.

Borax compounds have more lasting effect than chlorate but less than arsenicals. Borax compounds have less inherent toxicity to plants than either but are relatively non-poisonous to animals. They are applied at rates of from 800 to 1,600 lbs./acre.

Trichloroacetic acid, or TCA—the sodium and ammonium salts are very toxic in the soil to grasses but less to broad leaf plants. It is used on para, Bermuda and other grasses and is most effective as a spray when leached into the soil by rains. Its primary value is that it does not sterilize the soil for a very long period of time and can be used on agricultural lands. It is applied at rates of from 20 to 150 lbs./acre.

CMU or "Karmex" W is 3-(p-chlorophenyl)-1,1-dimethylurea. It is a highly active weed killer and very persistent due to its low solubility. It appears to be non-toxic to animal life and non-inflammable. Its safeness, plus high phytotoxicity, and long lasting qualities make it valuable for treatment where permanent sterility is desirable. It is applied at rates of from 10 to 50 lbs./acre.

Analogs of CMU are now available with toxic characteristics similar to CMU. One is somewhat more soluble and is less persistent in the soil, while another is less soluble and more persistent.

It may prove advantageous to use combinations of the above soil sterilants to utilized different desirable effects of each. For example, a

mixture of sodium chlorate and arsenic trioxide combines the rapid action of the chlorate with the residual property of the arsenic to offer a more effective treatment where both deep and shallow rooted plants are together.

SYSTEMIC HERBICIDES are compounds which are absorbed by the foliage or roots and are spread throughout the entire plant causing all of it, including roots, to be affected. They are of special value in control of emerged and floating aquatics where the root systems are covered by water. Many are selective in killing action. 2,4-D is the best known of this type; it will control most broad-leaf plants and not permanently damage grasses and grains. It is very effective on the water hyacinth. When used with proper adjuvants that allow the agent to penetrate the oily protective coating of the plants, it is effective against water lettuce, spatterdock, waterlily, cattails, spikerush and others. 2,4,5-T and its compounds are somewhat less selective than 2,4-D and are more effective on woody weeds and brush, being used on poison ivy, sedges and hardwoods. A combination of these two is frequently used as a general killer for broad-leaf plants. 2,4-D acid is used directly or is formulated into salts or esters. Most salts may be used in dusts or dissolved in water. The ester is miscible in oils only, but may form an emulsion in water. In general, 2,4,5-T is formulated in the same manner as 2,4-D, except the sodium salt is not used. The esters are more effective than the salts, but volatility and drift are much greater with esters with increased danger to surrounding crops. From 2 to 4 lbs. per acre of acid equivalent are effective for most uses. Both are non-toxic to animals at recommended rates.

Dalapon, -a,a-dichloropropionic acid, is a new plant growth regulator effective on grasses. It appears to be translocated from the foliage and also to be absorbed by roots following soil application. It is a new herbicide and tests are being conducted to determine plant selectivity and other information. It seems to be relatively non-toxic and safe to apply. It has given control of cattail, phragmites, spikerush and para grass. Since it is translocated it should prove a valuable herbicide for the aquatic grasses not affected by 2,4-D and other plants whose root zones cannot be reached by soil sterilants. It is applied as an aqueous spray at rates varying from 5 to 50 lbs. acid equivalent per acre.

Amino triazole is still in the early trial stage. It is similar in action on grasses to Dalapon and appears to be quite toxic to para grass. In tests at Plantation Field Laboratory rates of from 12 to 18 pounds per acre have yielded good results on para along canal banks.

THE HERBICIDAL OUTLOOK IN FLORIDA

Earl G. Rodgers *

The control of weeds is and always has been a basic part of crop production. Past methods of control have consisted largely of mechanical and cultural practices. Only during the last decade has intensive interest been shown in the use of chemicals, or herbicides, for weed control. Great strides have been made during these recent years in many parts of the world toward reducing costs of producing crops by properly combining mechanical, cultural, and chemical methods of weed control.

The use of herbicides has proved to be a paying proposition under varied conditions in many parts of the country. Increased crop yields with lower production costs have been common where herbicides were properly used. Weeds and brush usually can be kept out of fence rows much more easily and economically with chemicals than by mechanical means. Herbicides have greatly reduced the costs of controlling undesirable vegetation on rights-of-way of various kinds. An almost indefinite list of specific herbicidal uses can be found in the literature.

Weeds cost the American farmer more money every year than any other agricultural pest, considering costs of control and losses sustained during crop production. The total annual loss to weeds in the United States has been estimated from $2,261,000,000 to $5,000,000,000. Assuming these figures to be reasonably accurate and considering the extended growing season in our state, the great diversity of crop plants and soil types, the expansive, non-attended areas that often serve as huge weed seed reservoirs, and the intensity of aquatic weeds, Florida then experiences an annual loss to weeds probably between $75,000,000 and $125,000,000. Losses of such magnitude emphasize the need for organized effort directed toward reducing these figures. The outlook for herbicides in Florida seems to be great, then, as a possible means of realizing these reductions.

An effective herbicidal program of research and education is essential before Florida can realize the advantages offered by herbicides. Research findings must be of a local nature, since data from other areas often do not apply under different environmental conditions. Locally developed recommendations, then, should be available to the farmer for practical use.

In developing a program of work in a new field of science, such as chemical weed control in Florida, the leaders have no set pattern to follow and must feel their way. There are several state workers in Florida who have an active interest in the use of herbicides for controlling weeds in Agronomic and Horticultural crops. Individual programs have been initiated at the respective home stations of the various workers with basic objectives particularly applicable to problems in that area. Some outstanding results have been reached.

All of these individual programs have several points in common. Many of the same herbicidal compounds are included in several different tests. Numerous weed species exist in all parts of the state and present a com-

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mon problem of control. The behavior of herbicides in the soil may vary somewhat with local environmental conditions, but a given herbicide often shows similar response in many different types of soil.

With these characteristics common to all the individual herbicidal programs, it seems that state workers active in this field should correlate their programs very closely and thereby benefit from mutual exchange of results and opinions. Conferences, held annually or possibly semi-annually, to bring state workers together to exchange common thinking, opinions, and results would appear an excellent means of reaching this end. These conferences may have a rotating chairman and could be held at various locations in the state where an opportunity could be provided to observe existing problems and specific research work being carried out.

From such conferences may come recommendations for methods to bring about a closer working relationship among weed workers. It may be desirable to recommend the assignment of responsibility and authority for coordinating state herbicidal work to two persons, one in Agronomy and the other in Horticulture. These two persons of necessity must work together since many of the same herbicides would be used in the two programs and many of the same weed species would be encountered.

Or the conference may wish to recommend the assignment of certain areas of the herbicidal field to individual workers. For instance, the weed work in cultivated agronomic crops might be assigned to one person, brush control work to another, and weed control in pastures to still another. Naturally, there would be some overlapping of work with respect to herbicides used and weed species encountered. No serious difficulty would be anticipated, however, since results of each worker would refer to specific conditions where his work was conducted. Since the response of each crop variety to each herbicide must be known before specific recommendations can be made, a division of the work based on particular crops or types of crops appears to be very practical.

Industrial research plays an important part in the support of a state herbicidal program such as has been begun in Florida. The individual companies realize that their existence is dependent upon production of materials that will meet definite needs and the sale of which will yield them a reasonable profit. The industrial concerns attempt to reach that end with herbicides primarily by formulating and testing various new compounds in a preliminary way. If found to possess herbicidal properties, these materials may be released to state research workers for testing under specific conditions for definite uses.

Several of the larger commercial companies have their own research laboratories, some of which are located in Florida, where performance primarily of their prospective compounds is tested under field conditions. Much of this work may be and frequently is in support of state work being conducted to develop locally adapted recommendations. Under the auspices of the National Agricultural Chemicals Association, herbicide manufacturers have set up a program designed to encourage the expanded use of herbicides and has as one of its basic objectives to offer assistance in setting up and support of state weed control programs. Industry in general would prefer that specific recommendations for use of herbicides be made by state workers and upon request will actively support state programs having, either directly or indirectly, such goals.

Federal research also frequently offers basic support to state herbicidel programs. A Section of Weed Investigations in the United States Department of Agriculture has been in existence for about five years with its headquartes at Beltsville, Maryland. Federal workers include specialists trained basically in Agronomy, Soils, Plant Physiology, Horticulture, and many other fields and have contributed greatly to the recent phenomenal advance of herbicidal knowledge in the United States. Several such workers are assigned to specific weed problems in particular areas of the country, thereby offering direct support to individual state programs. Probably the scope of such Federal research will be expanded in the future.

Various aspects of extension work are included in the use of herbicides. To assist the average farmer in becoming sufficiently oriented to safely use herbicides is a huge task. Some states have Extension Specialists for this purpose who work either directly with the farmer or through County Agents. Representatives from the Florida Agricultural Extension Service probably would be interested in participating in such a conference as proposed above and contributing suggestions toward the development of practical recommendations. Comments and suggestions would come from such a conference that may be invaluable to the Extension man in correcting false impressions and bringing out necessary precautions in herbicidal work.

Chemical weed control is still in its infancy. However, remarkable progress has been made in developing common herbicidal uses. Herbicidal knowledge has advanced far beyond that envisioned by the most prominent workers ten years ago and with continued progress of this type, it is impossible to predict what the future might hold for this new field of science.

SOME SOIL AND WEATHER FACTORS INFLUENCING USAGE OF PRE-EMERGENCE HERBICIDES

W. B. Ennis, Jr.*

I. GENERAL NATURE OF PROBLEM

Soil and weather factors determine to some extent the success or failure of all herbicides currently available for farmer usage. Pre-emergence herbicidal treatments are especially subject to the vagaries of the weather. In the absence of any rainfall following treatment poor or no control of weeds is attained. In contrast many herbicides applied for foliar adsorption and translocation perform highly satisfactorily under the same conditions. The amount of rainfall occurring after pre-emergence treatments also governs the successfulness of the applications. Moreover, the stability of some herbicides is affected by the high soil surface temperatures that frequently occur in the Southern region.

Fortunately, in the humid Southeast, the lack of any rainfall after pre-emergence treatments to cotton, corn, peanut, and soybean in April and early May occurs only rarely—nevertheless, isolated areas sometimes experience droughty conditions during this period. More commonly, moderate to excessive rainfall can be expected during the period when crops are being established and it is under such circumstances that weeds present critical problems. A heavy emergence of weeds concurrently with the emergence of crops cannot be handled mechanically without a high hand labor requirement. It is such situations that have dictated experimentation to develop herbicidal procedures for controlling the weeds that emerge at about the time the crop plants begin growth. Thus, pre-emergence treatments, i.e., those made before the crop emerges from the soil, have been studied intensively.

It is under the weather conditions that favor growth of weeds that certain soil problems are presented as regards the safety with which an herbicide can be used on a crop. For instance, the extent of downward leaching, following rainfall, of herbicides determines to a great extent how selectively and efficiently an herbicide may control weeds. The composition and properties of the soil itself, which vary even within a given field on a single farm, not only determine the extent of downward movement but also influence the extent of herbicidal action on both crops and weeds, and persistence in the soil.

Thus, it is apparent that soil factors and the vagaries of weather offer complications to the pre-emergence usage of herbicides. At first glance it might be concluded that efforts to develop procedures to control weeds that are subject to factors so variable as soils and weather would meet defeat forthwith. Notwithstanding, it is reassuring that considerable progress has been made within the last 5 to 7 years in employing successfully certain pre-emergence herbicides to control weeds in row crops.

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I shall not attempt to outline progress that has been attained in usage of pre-emergence herbicides but to limit the discussion to some of the findings that have been made on soil and weather factors as they relate to successful use of pre-emergence herbicides and to point out where proper information is lacking glaringly.

II. DOWNWARD MOVEMENT AND HERBICIDAL ACTION IN SOILS

The selectivity of most pre-emergence herbicides is dependent upon a high degree of localization in approximately the top one-half inch of soil. Localization in this upper zone provides maximal concentration of chemical in the region most annual weeds germinate and minimal concentration in the soil zone that large crop seed germinate. Although there are a few instances where selected chemicals possess sufficient specificity of action that one species may be inhibited and another not affected, maximum localization of present herbicides within the upper one-half inch of the soil is generally a prime prerequisite for most efficient control of annual weeds and for safety to crops. Accordingly, the downward movement pattern and relative activity of pre-emergence herbicides in different soils under various weather conditions should be known before the materials are employed on a broad basis.

1. *Phenoxy Compounds.* Probably more studies have been made on the movement in soils of 2,4-D than any other pre-emergence herbicides in current use. Even so, the literature contains insufficient information on this valuable herbicide.

The amounts of clay and organic matter in soils are important factors regulating the extent of downward leaching of 2,4-D. In work done in Mississippi 2,4-D moved to greater depths in sandy soil than in clayey soils (18). According to Crafts (6), however, the retention of 2,4-D varies in such a way that neither textual grade nor parent material give clear clues as to the specific factors involved. Hernandez and Warren (9) reported that one surface inch of water moved highly toxic concentrations of 2,4-D to a depth of three inches in a soil containing nine per cent organic matter. There is also good evidence that 2,4-D may be leached completely from certain soils (8).

In contrast to the above reports, Muzik *et al.* (14) found that 2,4-D, sodium salt, failed to move beyond a depth of one inch on a calcareous soil with very high organic matter content, regardless of the amount of water applied; the high calcium and organic matter content was assumed to contribute to the immobilization of the 2,4-D. Aldrich (1) studied the downward movement of different forms of 2,4-D and found that esters were less subject to leaching than the acid and salt forms; he postulated that the esters were fixed by the soil to a greater extent than the other forms. Aldrich's (1) findings have been borne out by studies of Smith and Ennis (18) in that the polyethylene glycol butyl ether ester of 2,4-D was determined to move downward significantly less than certain salt forms and the acid of 2,4-D (Table 1). The manner by which the esters are fixed has not been clarified.

Because of the mobility of 2,4-D in most soils it is generally safe to use pre-emergently only on crops that possess considerable tolerance to the compound itself, e.g., corn, sugar cane and certain specialty crops. The low volatile ester formulations are preferred in the corn belt owing

to their apparent increased resistance to leaching in comparison to salt forms of 2,4-D. An understanding is largely lacking of how and why specific soil constituents may adsorb differently various forms of 2,4-D, or otherwise impede downward movement.

TABLE 1.—DOWNWARD MOVEMENT OF 2,4-D IN SOIL. THE RELATIVE CONCENTRATION OF THE HERBICIDE AT DIFFERENT DEPTHS IN THE SOIL DETERMINED BY MEASURING THE INHIBITION OF THE PRIMARY ROOT OF CUCUMBERS GROWN IN SOIL SAMPLED FROM PREVIOUSLY TREATED POTS. NUMBERS IN TABLE ARE MEAN ROOT LENGTHS (MM.) REPRESENTING 36-48 MEASUREMENTS. THE 2,4-D WAS APPLIED AT A RATE OF 6 MG. PER ½-GALLON POT (18).

Form of 2,4-D	Carrier	Depth Sample Taken				L.S.D.		C.V.
		0-1″	1-2″	2-3″	3-4″	5%	1%	
Caddo Fine Sandy Loam								
TEA salt*	Water	10.8	6.9	12.0	17.2	6.6	8 8	27.7%
Acid	Water	9.5	6.7	12.2	16.8			
Acid	Deobase + TBP**	8.8	8.4	16.9	23.2			
None (control)		34 2	30.1	25.6	28.0			
Houlka Clay Loam								
TEA salt	Water	8.2	23.4	32.8	33.3	6.0	8.0	14.2%
Acid	Water	8.8	23.7	35.3	27.3			
Acid	Deobase + TBP	11.1	24.2	32.6	34.3			
None (control)		44.5	44.6	40.9	45.9			
Houlka Sandy Loam								
TEA salt	Water	8.7	11.7	25.2	28.7	6.2	8.4	18.4%
Sodium salt	Water	9.2	12.6	26.0	28.0			
Glycol ester†	Diesel oil	11.6	23.4	26.3	30.8			
None (control)		33.1	36.0	36.4	33.7			
Houlka Clay Loam								
TEA salt	Water	13.1	20.6	48.7	—	12.5	16.7	22.5%
Sodium salt	Water	10.3	21.6	52.2	48.0			
Glycol ester	Diesel oil	16.0	40.3	43.2	46.7			
None (control)		62.7	56.0	57.2	53.2			

* Triethanolamine salt.
** Tributyl phosphate.
† Polyethylene glycol butyl ether 2,4-dichlorophenoxyacetate.

Insufficient data have been accumulated on the movement pattern in soil of derivatives of 2,4-D, such as sodium 2,4-dichlorophenoxyethyl sulfate and other phenoxy compounds, e.g., MCP and 2,4,5-T.

2. *Dinitros.* The dinitros have been observed to leach downward readily in most soils following rainfall and therefore problems are frequently presented as regards adequate control of weeds and safety to crops. Because the dinitros exert their toxic action on plants largely by contact, some large-seeded crops are capable of tolerating small amounts

TABLE 2.—SUMMARY OF THREE EXPERIMENTS ON THE DOWNWARD MOVEMENT OF 3-CHLORO IPC IN SOILS. THE RELATIVE CONCENTRATION OF THE HERBICIDE AT DIFFERENT DEPTHS IN THE SOILS DETERMINED BY MEASURING THE INHIBITION OF THE PRIMARY ROOTS OF CUCUMBERS GROWN IN SOIL SAMPLED FROM PREVIOUSLY TREATED POTS. HERBICIDE APPLIED IN 2 ML. SOLUTION PER POT. WATER ADDED AFTER TREATMENT EQUIVALENT TO ⅜ OR ½ INCHES RAINFALL. NUMBERS IN TABLE ARE MEAN ROOT LENGTHS (MM.) REPRESENTING 36-48 MEASUREMENTS (18).

Depth Sample Taken (in.)	Formulation and Carrier					L.S.D.		C.V.
	40% Emul. in Water	40% Emul. in Oil	Technical in Oil	Technical in Acetone	Control	5%	1%	
Sandy Clay Loam (20 mg./½ Gallon Pot)								
0-1	8.0	9.1	8.4	—	21.1			
1-2	25.9	24.2	24.6	—	25.6	4.7	6.3	13.8%
2-3	20.6	22.0	25.4	—	23.4			
3-4	22.8	19.7	22.8	—	24.1			
Sandy Clay Loam (12.5 mg./½ Gallon Pot)								
0-1	9.2	12.2	11.6	9.3	28.0			
1-2	36.9	32.3	36.9	36.2	38.2	6.0	7.9	14.1%
2-3	38.2	34.0	36.2	34.7	32.6			
3-4	35.5	35.6	34.7	34.3	30.1			
Kaufman Sandy Loam (12.5 mg./½ Gallon Pot)								
0-¼	9.0	8.8	10.6	—	34.2			
¼-½	12.7	17.4	22.1	—	34.3	4.4	5.8	13.2%
½-1	15.4	30.3	26.8	—	33.8			
1-2	30.0	27.5	30.8	—	31.0			

of the compounds moved downward to the zone of seed germination by percolating water.

Davis *et al.* (7) have applied varying amounts of simulated rainfall to two soils previously treated with DNBP. They found (a) that the larger the amount of water added the greater was the downward movement of DNBP in the soils, (b) that the material leached downward more in Norfolk sandy loam than in Deer Creek silt loam and (c) that water-soluble DNBP was more mobile in soil than an oil-soluble form. Following application of 2 inches rainfall equivalent they found that the materials moved downward to a depth of 6 inches. The work of Davis *et al.* (7) shows rather conclusively that the material is markedly diluted in some soils by rains of 2 inches. Accordingly, poor control of weeds under excessive rainfall conditions may be attributed to the presence of insufficient DNBP in the top layers of soil to control the weeds. The DNBP may also be hazardous to the crop if toxic amounts accumulate in the region of the germinating seed.

3. *The Carbamates.* The substituted N-phenyl carbamates are a group of herbicides that show striking selectivity and specificity of action. The most widely used of the carbamates, isopropyl N-3-chlorophenyl carbamate (CIPC), has a high degree of selectivity when used pre-emergently in some crops and this may be attributed in large measure to its resistance to downward leaching by rainfall. Although extensive studies have not been done, work amply demonstrates that under moderate rainfall conditions most CIPC is localized largely in the top one-half inch of soil (Table 2).

More recently, some newer carbamates have displayed more striking specificity of action than CIPC. The movement patterns of the materials in soils have not been determined but information on this characteristic as regards different soils is mandatory before they are utilized on a practical basis by farmers.

4. *The Ureas.* With the introduction of 3-(p-chlorophenyl)-1,1-dimethylurea (CMU) in 1951 there was made available to weed research men a compound of unusually high potency and for the first time, an organic material was introduced that had enough stability in soil to offer great promise as a soil sterilant. Since that time other interesting and potent members of the urea family have been added. Investigators have found that not unlike DNBP, 2,4-D and some other materials, the safety with which the ureas can be used is influenced by soil characteristics and rainfall. On cotton the range in dosage to obtain weed control and to avoid crop injury is narrow, i.e., between one and two lbs. per acre for most soils. Some other crops possess insufficient tolerance to the materials for them to be used with safety.

Relatively little work has been reported on the movement of the ureas in soils. Work done in Mississippi on CMU, 3-(3,4-dichlorophenyl)-1,1-dimethylurea, and 1-(3,4-dichlorophenyl)-3-methylurea showed that after 5 months and the occurrence of 18.4 inches of rainfall the ureas were localized virtually altogether within the top one inch of soil (Table 3). The soil in this instance was Una clay loam. These results are in general agreement with those obtained by Loustalot *et al.* (13) in Puerto Rico where they found that CMU did not move downward appreciably beyond the first inch of soil when up to one inch of rainfall equivalent was ap-

plied. It is known from field observations that on porous soils the materials move downward in sufficient quantities to damage crops planted up to two inches deep. Moreover, at high dosages CMU has been observed to move to depths of 12 inches or more.

TABLE 3.– DOWNWARD MOVEMENT IN UNA CLAY LOAM OF THREE SUBSTITUTED UREAS AS SHOWN BY THE RESPONSE OF RADISH. RADISHES WERE GROWN IN SAMPLES OF FIELD SOIL TAKEN FROM 0-1, 1-2 AND 2-4 INCH DEPTHS, FIVE MONTHS AFTER APPLICATION OF THE MATERIALS. RAINFALL TOTALED 18.4 INCHES DURING THIS PERIOD (10).

Herbicide	Lbs./A.	Percent Kill of Radish		
		0-1 Inch	1-2 Inch	2-4 Inch
3-(p-chlorophenyl)-1,1-dimethylurea (CMU)	1	0	0	0
	2	100	0	0
	4	100	52	0
3-(3,4-dichlorophenyl)-1,1-dimethylurea (DCMU)	1	2	3	0
	2	86	0	0
	4	100	4	7
1-(3,4-dichlorophenyl)-3-methylurea	1	2	0	0
	2	8	0	0
	4	66	2	0
	6	45	0	0
Control	0	0	0	0

Studies by Sherburne and Freed (17) have demonstrated that organic matter and clay particles adsorb CMU, thus the downward movement of the material would be expected to decrease with increasing clay or organic matter content. Organic matter has an unusually high affinity for CMU and therefore to obtain equal weed control higher dosages of the material are required on soils high in organic matter than on those low in organic matter, as typified by many soils of the South.

Much additional information is needed on the movement patterns in different soils where the urea materials may have potential usefulness as pre-emergence herbicides.

5. *Other Organics.* Several newer herbicides belonging to other families of compounds have shown promise as pre-emergence herbicides. Among them are N-1-naphthyl-phthalamic acid, disodium 3,6-endoxohexahydrophthalate (Endothal), 3-amino-1,2,4-triazole, certain benzoic acids, and others. Little or no information is available concerning their behavior in soils.

III. PERSISTENCE IN SOIL

The fate of herbicides in soils depends on several factors, which includes—properties of the soil itself, temperatures, rainfall, and the chemical stability of the herbicides involved. The major losses of herbicides from soils occur from leaching, physical and chemical inactivation, and biological decomposition.

1. *Loss by Leaching.* Leaching of some herbicides is determined largely by the amount of water that passes into and through the soil after the chemical is applied. Soil type affects the distribution of these materials in the same way that it affects water distribution. For example, heavy soils retain more water than coarse soils and therefore if the same amount of water is added, a greater proportion of water will move through the coarse soil, carrying the herbicide with it. Accordingly, the loss by leaching of herbicides is inversely related to the moisture-holding capacity of the soil. Leaching of herbicides by rainfall or irrigation promotes not only loss of herbicides *per se* but also distributes the materials so that other forces can react to inactivate them.

2. *Physical Inactivation.* Work done with inorganic herbicides has shown that some soils have an affinity for certain chemicals. For example, the borates are held more firmly in soil than the chlorates. Clay particles and organic matter are the two constituents of soil that appear to adsorb herbicides most readily. Accordingly, soils high in organic matter or high in clay content usually require higher dosages of pre-emergence herbicides, to obtain equivalent weed control, than soils low in these components. Correspondingly, the responses of crops to the herbicides vary because of these same relationships.

Sherburne and Freed (17) found that a muck soil (83.3% OM) adsorbed 150 times more CMU than a sand soil containing 0.9% organic matter. Widely different rates of CMU would be required between these two soils to accomplish the same weed control. Apparently, the herbicide in the solution phase, or that only loosely adsorbed, is the only part that is biologically active. Certain other herbicides including 2,4-D appear to be similarly influenced by organic matter and clay content. More precise information is required on the specific effects various soil components and soil reactions have on the activity and behavior of herbicides in different soils.

3. *Chemical Decomposition.* Some materials become inactive in soils because of reactions with the soil water. The new herbicide 2,2-dichloropropionic acid is easily hydrolyzed and therefore may persist for a relatively short time in moist soils. Although good information is lacking it is believed that chemical decomposition plays a minor role, however, in the disappearance from soils of the most commonly used pre-emergence herbicides. Volatility losses are important but this subject will be treated later.

4. *Biological Inactivation.* Probably the most important losses of herbicides from soils result from the activity of microorganisms. Factors that are conducive to the highest microbial activity also favor the most rapid disappearance of chemicals from soils; for example, optimum moisture and temperature are highly important. Moreover, the presence of adequate nutrients and organic matter favors growth of microorganisms which in turn hastens biological breakdown of herbicides in soils.

A. S. Newman (15) and co-workers at Camp Detrick, Maryland have discovered certain soil organisms capable of decomposing fantastic amounts of 2,4-D within a few days when the populations are increased by repeated treatment of the culture medium with 2,4-D. Evidence has been obtained to indicate that the organisms responsible for the breakdown are rather specific in that pre-treatment with closely related phenoxy

compounds in some instances, has no effect on the persistence of 2,4-D (16). Evidence has also been obtained that IPC and CIPC are decomposed by soil microorganisms. Work by Loustalot *et al.* (13) and investigations by Weed *et al.* (19) show that the urea compounds may be decomposed by microorganisms but the process is slow and efforts to speed up their decomposing action on the ureas by practical means have met with poor success.

Thus, microorganisms play a tremendously important role in depleting soils of herbicidal materials. A more complete understanding is needed of the specific organism or organisms which are capable of decomposing a particular material. Moreover, it is important to know their occurrence and distribution in different soils and regions. Although the amounts of herbicides used on cropland as pre-emergence treatments are not believed to have important adverse effects on the microbial populations of soils (15, 4, 5), these aspects warrant more attention by soil microbiologists.

IV. VOLATILITY PROBLEMS

Most herbicidal compounds have relatively low vapor pressures and in the general physio-chemical sense would be considered non-volatile. Notwithstanding, the high biological activity of some materials in extremely low concentration, for example certain 2,4-D esters, has made necessary the development of a new concept regarding volatility and has prompted several studies on the volatility of phenoxy compounds. High temperatures favor volatilization of 2,4-D compounds but some low-volatile esters have been prepared that have greatly mitigated 2,4-D vapor injury problems. Where 2,4-D causes injury to non-sprayed plants under field conditions, the contamination more commonly results from actual drift of spray particles rather than from vapor. The importance of 2,4-D vaporization from soils as regards loss of weed control efficiency is not usually considered important. However, the high soil surface temperatures that occur in the Southern states probably cause sufficient vaporization to account for the poor control of weeds sometimes obtained from 2,4-D pre-emergence applications. Loss of water vapor from soil is known to be important in the vaporization of certain compounds but little or no work has been done with the phenoxy compounds to determine whether or not herbicidal vaporization is related to water vaporization.

Volatilization of the substituted phenols caused rather widespread damage to cotton in the Mississippi Delta in 1952. There was much consternation when the injury first occurred and it was only after considerable work that the cause of the injury was diagnosed and the factors contributing to the vaporization were understood (11, 10, 3, 12). We now know (a) that under some conditions the dinitro compounds will produce vapors toxic to cotton (Table 4), (b) that temperature is probably the outstanding factor which contributes to volatility of the dinitros—above 85-90° F. the activity is high, and (c) that the loss of water vapor from the soil is also a prerequisite to dinitro vaporization. Moreover, a soil acid in reaction is more conducive to the phenomenon than alkaline soils.

The carbamates IPC and CIPC also present volatility problems but their vapors are not particularly damaging to crops under field conditions.

The chief disadvantage of their volatilization is a possible reduction in weed control effectiveness. Work published by Anderson *et al.* (2) indicated that as much as 80-90 per cent of CIPC coating on glass slides was lost by vaporization within about 24 hours at 85° F. We know that the loss from soil is far less and under some conditions is insignificant. Notwithstanding, the material is volatile (Table 4) and lack of proper weed control from CIPC treatments in some instances is probably due to losses by vaporization to herbicidally innocuous levels. More work is needed to determine the important factors involved in the loss from different soils of the carbamates as well as other important groups of compounds.

Vapor loss of the urea compounds from soils is considered unimportant but precise data on this group of materials are inadequate.

TABLE 4.—Vapor Activity of CIPC and DNBP as Measured by the Response of Cucumber and Cotton Seedlings. Seed Planted April 25, 1953 in Metal Pots and Placed Under Glass Cases (20 x 20 x 20 in.) Containing Trays of Soil Treated with CIPC or DNBP. Temperatures Ranged Between 76° and 107°F. During the Exposure Period of One Week. Measurements Made May 19, 1953.

Compound	Lbs./A. in 12 x 18 In. Tray	Cucumber Response (Mean Length (mm.) First Foliage Leaf)		Cotton Response[1]	
		Case I	Case II	Case I	Case II
CIPC	6	8.0	7.8	*	*
DNBP	6	59.2	61.8	***	***
Control	0	57.0	60.5	*	*

[1] * No noticeable response.
** Slight chlorosis.
*** Moderate chlorosis and leaf burn.
**** Severe chlorosis and leaf burn.
***** All plants dead.

An attempt has been made to survey some of the various soil and environmental factors which influence usage of pre-emergence herbicides. This subject has been dealt with in a sketchy manner owing to space limitations, but it is apparent that the information needed far exceeds what is known. An increased interest of soil physicists, soil microbiologists, and other soil scientists in providing information on these important soil phases of herbicidal usage would fill important gaps in our programs of weed control research. Simple laboratory or field techniques are needed whereby the downward movement, relative herbicidal activity, and persistence in soils of promising pre-emergence compounds can be predicted with reasonable accuracy. In time there may be a need to set up laboratories along the lines of our soil testing labs where farmers can have their soils analyzed and from the information obtained on the soils together with basic data on the properties of the herbicides themselves it may be feasible to make sound recommendations on whether or not the farmer should use a particular herbicide, the amount to use, and when and how to apply it to obtain maximum benefits. Modern weed

control is rapidly developing into a science but it needs the participation of workers trained in certain of the other physical and biological sciences to help provide answers to some of the knotty problems. Certainly persons trained in soil science are in a position to render valuable service by cooperating in those phases of weed control research where soil problems are limiting progress.

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EXPERIENCE OF THE DADE COUNTY WATER CONSERVATION DISTRICT IN CONTROLLING WATER HYACINTHS AND WATER WEEDS

F. D. R. PARK *

Since the latter part of 1945, the Dade County Water Conservation District, under the direction of E. A. Anderson, County Engineer, has endeavored to rid the county canals of water hyacinths (*Eichornia crassipes* (Mart.) Solms) and weeds in order to improve drainage and provide for a better distribution of fresh water during low water periods. Dade County's experience in applying some of the methods of control, and the costs involved are discussed herein.

The Dade County District, in its efforts to control the growth of water weeds throughout the County, is indebted to the Soil and Water Conservation Branch, Agricultural Research Service, U.S.D.A., and in particular to Mr. John C. Stephens, Research Project Supervisor at Ft. Lauderdale, Florida, for many valuable suggestions rendered in the past. The outline of types of water weeds and methods of control presented in his current paper will be of great value to all agencies of this area now engaged in applying the principles involved.

CONTROL OF WATER HYACINTHS

The Dade County Water Conservation District has been spraying hyacinths since September 1946. At that time, and even until early 1949, many of the important canals of the county were periodically choked by heavy growths of hyacinths. Beginning with the larger canals first, because of the greater capacity available in those channels, and proceeding gradually westward into the smaller canals and ditches, growth of hyacintchs was checked, and since early 1949 has been controlled in all of the major canals by repeated spraying with 2,4-D. Conditions prior to 1949 when the spraying program became effective, as compared with improved conditions since that year, are illustrated by typical views shown in Figures 1 and 2, respectively.

Spraying Procedure.—The usual method of application of 2,4-D has been spraying from a work boat as indicated in Figure 1. However, in many instances it has been expedient or necessary to mount the spraying equipment on a truck and spray from the bank. Sometimes this is necessary to obtain an initial clear pathway for movement of the spray boat on subsequent passes; also, it has proven economical occasionally for a small crew in a boat to use forks in throwing hyacinths from the water onto the bank in areas of scattered or fringe growth along the water edges. These methods, particularly spraying from a good sized aluminum work boat, have proven so successful that the use of a dragline bucket has been resorted to only in cases where cleaning, deepening, or other improvements of the channel were required regardless of degree of hyacinth

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growth. The County has used the Amine formulation of 2,4-D for the past three years, which has 4 lbs. of acid equivalent per gallon of liquid. The concentration of spray used has averaged about 1 gallon of commercial liquid per 100 gallons of water, and a detergent has been added to produce better adherence to the hyacinth leaves. Present usage is 5½ quarts of 65% 2,4-D liquid and 1 box of "Dreft" in 140 gallons of water in the spray tank.

Figure 1.—Opa Locka Canal in January 1949. This represents typical condition earlier in spray program. Typical present conditions are fringe areas of hyacinths along banks sprayed from a larger work boat by using the same spray rig and three men.

Rate of Spraying and Costs.—The estimated rate of application of spray material and the costs involved are sumarized in Table 1. Cost of spray material averages about $1 per pound of 2,4-D acid; labor costs

are based on a 3-man crew; and equipment costs include usage of a pole truck and trailer for transfer of boat and spray equipment, also cost of the spray tank and machine. There has been very little need for heavy applications since early 1949, the only area requiring such treatment being far west of any county area proposed for development. It will be noted from Table 1 that for the past five years the field cost has averaged about $4,800 per year for hyacinth control, and somewhat over $19 per acre of hyacinths sprayed.

Figure 2.—Same reach of Opa Locka Canal west of N.W. 27th Ave., October 1954. Canal has been kept free of hyacinths since 1949.

Although amounts of liquid, numbers of man-days, and equipment data were available for obtaining costs of material, labor, and equipment, there are no actual records of exact measurements of length of canals covered per unit of time, area hit by spray, or area actually covered by water hyacinths. The most uncertain of the data in Table 1 is the estimate of the size area sprayed in unit time, and no estimate is made as to what proportion of that area is actually covered by hyacinths. The nearest thing to a reconciliation or check on such data in the table is that the relation between 193 gallons of diluted spray per acre and an average 6-ft. width of fringe area for the known mileage of canals patrolled seems reasonable because of the high percentage of kill obtained, visualization of width sprayed, and the length of canal reaches known to be repeatedly

infested. The most significant information resulting, of course, is the fact that 63 miles of canals approximately 40 ft. wide are being kept free of water hyacinths at a field cost of about $4,800 per year, or a little over $76 per mile per year. The county's concern in these spraying operations has been to obtain practical results at reasonable cost, and we feel that this has been accomplished.

TABLE 1.—ESTIMATED FIELD WORK AND EXPENDITURES FOR HYACINTH ERADICATION. 1950-1954 Incl.

Item	5-Yr. Total	Per Year 5-Yr. Average
Work Days, 3 men spraying	316	63
Work Days, 4 men using forks	64	13
Work Days, total	380	76
Liquid, 65% 2,4-D, gallons	2,200	440
COSTS:		
Liquid ($4/gal.)	$ 8,800	$1,760
Labor and Equipment ($40/day)*	15,200	3,040
Total	$24,000	$4,800

Estimated Rate of Application of 2,4-D, and Cost/Acre:

Estimated length of canal sprayed (2 banks), per day	2.5 miles
Estimated length of canal sprayed (2 banks), per year	157 miles**
Estimated width of average fringe area sprayed, each bank	6 feet
Estimated area of hyacinths and weeds hit equiv. to 12 ft. width	1.45 Ac./Miles
Annual coverage (area hit by spray)	228 Acres†
Rate of 2,4-D application, diluted $\left(\frac{440 \times 100}{228}\right)$	193 Gallon/Ac.
Rate of 2,4-D application, acid equivalent	7.7# Acre
Annual cost of spray operation (†)	$4,280 or $18.70/Ac.
Annual cost of spraying and forking	$4,800
Annual cost of spraying and forking, 63 miles	$ 76/Mile

* Equipment at $8/day; same daily cost spraying or forking because 3 men spraying plus equipment is equivalent to 4 men forking.

** Equivalent to about 2½ "rounds" per year along the 63 miles of canals Nos. 1-8, Table 2.

† The area hit is greater than actual area covered by hyacinths in fringe on spot spraying, which is the typical condition for this table. Therefore cost/Acre of hyacinths is somewhat greater than $19.

The mileage of the various canals which has been cleared of hyacinths, and being kept free, is estimated in Table 2. About 194 miles of canals, varying from 15 to 100 feet in width, are being patrolled (inspected) because hyacinths may be found at some sites periodically in any portion of the reaches indicated. An estimated 2½ "rounds" per year of 63 miles each, or 157 work miles annually, are required to keep hyacinths out of the 194 miles of channel subject to infestation.

TABLE 2.—DADE COUNTY CANALS PATROLLED FOR WATER HYACINTHS AND WEED CONTROL.

No.	Canal or Ditch	Length Miles	Ext. Approx. Width Feet	Currently Patrolled Miles*		Remarks
				To Spray Hyacinths and Weeds	To Drag for Water Weeds (By Duck)	
1.	Snake Creek to 67 Ave.	10.5	120	—	—	No current work ac. recent improvement by C.E.
2.	Bisc. to Red Rd. incl. Spurs 1, 4, and Opa Locka	22.5	65	19.0	17.0	Also paragrass and occasionally algae.
3.	Little River to Red Rd.	8.5	50	6.0	5.0	Some para grass, also.
4.	Red Road (North)	9.5	15	9.5	1.5	Also algae and para grass; trying Dalapon now.
5.	Tamiami, to D-B levee	13.5	60	9.0	8.0	Lower 5 miles kept clean; back 4 miles to do.
6.	Comfort	3.5	40	3.0	2.5	Sometimes water lettuce for 1 or 2 miles.
7.	Coral Gables, to Trail	7.5	40	4.5	4.0	Very few to no hyacinths recent years.
8.	Snapper Creek, to Trail	12.5	45	11.0	11.5	Under major improvement—very few hyacinths recently.
9.	Snapper Creek, Ext. North	7.5	35	7.5	7.5	No dragging yet, but will be.
10.	Peters Pike	5.0	20	5.0	d.l.**	
11.	Grahams Road	5.5	18	5.5	d.l.	
12.	Gratigny Road	4.0	15	4 0	d.l.	
13.	Ludlam Rd. (North)	2.0	20	2.0	d.l.	
14.	E. Glades	1.5	20	1.5	d.l.	
15.	Miami C., to levee	20.0	95	12.0	14.0	Very few hyacinths ever found.
16.	North Line, to levee	10 5	33	6.5	6.5	West 4 miles not now patrolled, but will be.
17.	Dressels	6.0	20	6.0	d.l.	
18.	F.E.C., incl. Borrow	7.0	30	7.0	d.l.	
19.	Melrose	2.5	78	2.5	d.l.	
20.	Levee Borrows (County)†	33.0	55	33.0	—	No dragging as yet; will drag 10-15 miles later.

(Continued on next page)

TABLE 2.—Dade County Canals Patrolled for Water Hyacinths and Weed Control.—(Continued).

No.	Canal or Ditch	Length Miles	Ext. Approx. Width Feet	Currently Patrolled Miles*		Remarks
				To Spray Hyacinths and Weeds	To Drag for Water Weeds (By Duck)	
21.	Bird	6.0	25	6.0	1.5	
22.	Krome	5.0	25	5.0	—	
23.	132 Ave.	2.0	25	2.0	2.0	
24.	Cutler Drain	1.0	—	1.0	—	Dozer cleaning—no actual channel.
25.	County Hosp. Ditch	1.0	20	1.0	d.l.	
26.	Miller Road Ditch	2.5	22	2.5	d.l.	
27.	Coral Way Ditch	2.5	15	2.5	d.l.	
28.	Black Creek	3.5	30	3.0	d.l.	
29.	Goulds	3.5	30	2.0	d.l.	Bank maint. by mowing machine begun past 6 months.
30.	Military	5.0	35	2.5	d.l.	Bank maint. by mowing machine begun past 6 months.
31.	Mowry	3.0	40	1.5	d.l.	Bank maint. by mowing machine begun past 6 months.
32.	North	7.5	50	4.0	d.l.	Bank maint. by mowing machine begun past 6 months.
33.	Fla. City	9.0	50	6.0	d.l.	Bank maint. by mowing machine begun past 6 months.
	Total miles	244	44± Avg.	194*	82*	

* Since 1949 shorter reaches than shown are actually being reinfested by hyacinths. About 63 miles being sprayed for hyacinths; and 40 miles dragging by duck.

** d.l. means under-water maintenance by dragline only, at least up to present (D.L. also in use periodically on nearly all other canals listed).

† Excl. 24 mi. Government levee borrow (L-30, 31) where no maintenance required yet—to be by C&SFFCD.

Related Problems and Experiments.—The county canals for several years have been free enough of hyacinths that when rain or wind conditions are adverse, the program is discontinued until the spray can be fully effective, or until there is little or no danger to crops and shrubbery along the canal banks due to drifting of the spray. Damages from this cause have been very slight because careful attention has been given to these conditions. In a few areas water lettuce has at times become established in the canals and first attempts to eliminate it were not very successful. In 1951 a mixture of 5 gallons of Xylol (Xylene) and $\frac{3}{4}$ pint of Triton X-155 was added at the rate of 1 gallon to each 50 gallons of 2,4-D spray as used in the field. The resulting mixture was applied to water lettuce or water bonnets (*Pistia stratiotes* L.) without much success, the lettuce becoming established again within a few weeks. In 1954, upon recommendation of Mr. J. C. Stephens, a mixture of 3 pounds TCA to each pound of 2,4-D acid equivalent was used with the result that a good kill of water lettuce was obtained within a few days. This treatment will be tried again as soon as the need arises.

Some experimental work has also been done in applying chemicals to maiden cane (*Panicum hemitomon* Schultz.), cat tails, (*Typha* spp.), and para grass (*Panicum purpurascens* Raddi.), however, results and costs are not known with enough certainty to provide data herein. In recent weeks a test application of 25 pounds of Dalapon per acre has been used in a roadside ditch which was filled with para grass and cat tails. Results of this test are not known as yet. Sodium TCA has been found to kill para grass on the ditch banks but did not kill the grass which grows in the water.

CONTROL OF WATER WEEDS

With reference to eradication of underwater weeds by chemical means, investigations by this office, in cooperation with the Agricultural Research Service, U.S.D.A., have indicated that such methods are as yet too expensive for practical use in Dade County. The cheapest material which would be effective appears to be emulsified gasoline but even this, at the rates of application required for effective results, are far too costly for serious consideration, especially when this method is compared with mechanical and other means of control of these weeds.

Mechanical Method Used.—The most effective and economical method of controlling underwater weeds as yet developed by Dade County is dragging of the channel by an amphibious duck. This method is illustrated in Figures 3 and 4. The main infestation in the canals, since hyacinths as a major problem has been brough under control, is Naiad (*Najas guadalupensis* Spreng.) and Coontail (*Ceratophyllum demersum* L.) both of which grow from the bottom of the channel and have long streamers. Ramps have been constructed in several reaches of the canals which are most susceptible to this growth, and the duck is driven into the canal at these ramps and is taken out by the same means wherever necessary to bypass bridges or culverts. The drag is of V-type steel beam construction as indicated in the photograph. It is towed at a distance of 80 to 140 feet from the duck, the distance being adjusted by the

cable winch mounted on the rear of the duck. Dragging proceeds both upstream and downstream and as many passes are made in each direction as necessary to tear loose and dislodge water weeds and grasses throughout the center of the channel first, and then as near the banks as practicable.

Figure 3.—Amphibious duck used for dragging canals to remove water weeds, also to assist in removing masses of weeds accumulating against bridge piers. (A portion of boat and spray rig used for hyacinth spraying is seen on right edge of figure.)

Figure 4.—Use of amphibious duck and V-type drag is illustrated on edge of ramp into Coral Gables Canal in golf course area.

Because of the mass of water weeds cut free in areas where the growth is heavy, this operation often necessitates a crew with a pole truck or small dragline at bridges downstream from the site of operations, for dislodging or removing the accumulation of weeds on bridge piers. Water weeds have become a far greater menace to flood control and a greater problem in canal maintenance in recent years than water hyacinths, and as a result the County has constructed and operated two types of experimental mechanical weed cutters which will be described subsequently. However, costs based on experience with the duck and drag over the last year have proven so much cheaper than other equipment experimented with that the county now has two ducks in operation for almost continuous dragging to control water weeds.

Figure 5.—Experimental barge type towing rig using V-type drag on Tamiami Canal. This rig is somewhat slower than the duck, and removal at bridges is required in order to proceed along the canals. Rig is powered by V-8 Ford motor.

Cost of Dragging Canals with Duck.—The period of operation of a duck by the County is too short for compiling accurate costs. The County has paid approximately \$2,600 each for the used amphibious ducks which it now uses. During the past year one duck has patrolled and kept clean about 40 miles of canals at a low cost which indicates that this is the most economical operation the County has performed in improving canals. The 40 miles of canals (parts of Canals Nos. 2, 3, 5, 7, 8, 9, and 16, in Table 2) have been dragged repeatedly—an average of 4½ "rounds" in one year. This work has been accomplished at a total estimated cost of about \$9,000, which is equivalent to \$50 per work mile or \$250 per mile of canal kept practically free of under water weeds for one year.

Because of the serious reduction in canal capacity resulting from heavy growth of these weeds—up to 80 or 90 per cent reduction during

periods of extreme infestation—it is believed that more benefit per dollar expended on canal maintenance is realized by this dragging procedure than by any other maintenance work on the County's canals. The resulting improvement is considered to be worth many times the cost involved, and despite comparative high maintenance costs for amphibious vehicles due to relative scarcity of parts for replacements, there seems little doubt but that the County's plan for increasing this type of operation is well justified.

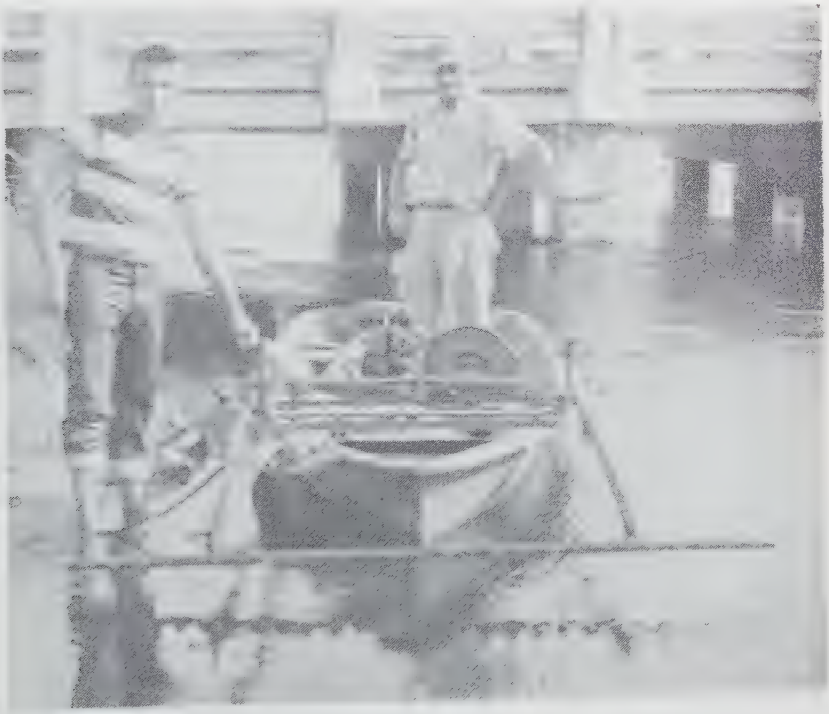

Figure 6.—View of portable type commercial weed cutter with mowing machine type blades horizontal and vertical, being demonstrated in Dade County Canal—Snapper Creek at Trail.

Experiments with Mechanical Drags and Cutters.—Experimental work on mechanical cutters has included a trial barge-type towing rig which was in operation for a short period on the Tamiami Canal. This device is illustrated in Figure 5. This is a 2-man rig operated hydraulically, equipped with a Ford motor, and using the same type of propeller and shaft as used in the amphibious duck. The same V-type cutting bar was towed behind this rig as is used behind the duck. Vertical clearance was kept low for passage under small bridges. This towing rig cost more than the amphibious duck, it was slower in operation, and was much more difficult to transport or move from one reach of the canal to another when passage was stopped by bridges than is the amphibious duck which can enter and leave the canal by way of ramps. Use of this

rig also necessitated a crew at bridges and culverts downstream for clearing away floating material cut loose by the drag.

Figure 7.—View of experimental weed cutter using weedless wheel as cutter. This cutter is successful in chopping up the weeds, leaving a clean canal, but proved to be too costly of operation for extensive use.

Figure 6 is a view of a weed cutter which was demonstrated on one of the County canals. It is a portable rig which has low clearance, is propelled by an outboard motor, and has mowing machine type cutting blades, both horizontal and vertical. The same Company manufactures a larger barge-mounted type mechanical cutter which has paddle type propulsion and is not dependent on an outboard motor in that regard. The larger rig can cut to depths of 5 feet whereas the small cutter can reach to depths of 4 feet; the larger rig has one power unit for operation of both the cutter and for propelling the boat by a paddle mechanism in the rear. The cost of these cutters runs from about $450 for the light portable equipment to $1,300 for the larger barge type. The horizontal blade can be set at various depths and the vertical cutter keeps a pathway free for movement of the boat. The vertical cutter can also be used for cutting free large accumulations of weeds around bridge piers.

Another experimental rig which was devised by Mr. Erban Cook, in charge of the Dade County Shop, is illustrated in Figures 7 to 9. This was a hydraulically controlled weed cutter, movement of the barge being

a walking operation by means of pipe spuds. It will be noted that a weedless wheel is used for the weed cutter. It is so designed that the long plumes and streamers of Coontail and Najas are sucked into the wheel and then chopped into fine pieces. This equipment proved to be successful insofar as elimination of weeds is concerned, and particularly would be of great advantage in eliminating the necessity of cleaning bridge piers because of accumulation of material cut free by the weed cutter. However, it was found that progress in the weed cutting was too slow for the operation to be economical. It was possible to obtain a very clean canal bottom at a steady rate of progress of 2,400 square feet an hour. The cost of operation on this basis where the canal was fairly well covered with water weeds, would be over $440 per mile which was considered excessive especially in view of the fact that the weeds began growing back at a rapid rate after about 6 weeks or 2 months. Experience with this rig and the barge towing rig mentioned above led to the decision to purchase surplus army ducks for eliminating underwater weeds.

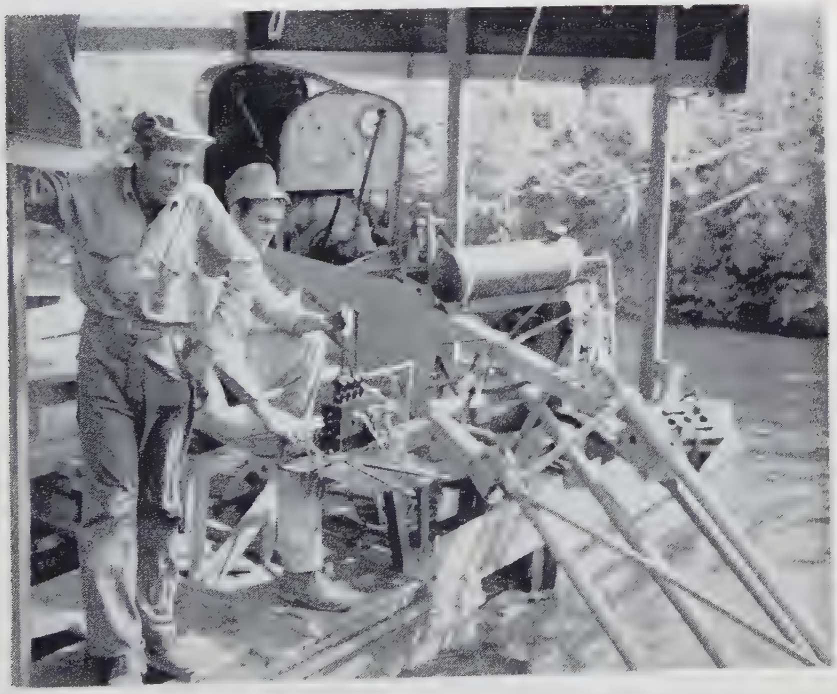

Figure 8.—Closeup of hydraulic mechanism for operating weedless wheel type cutter. Power is by V-8 Ford motor.

"Bankers" and Bank Work.—In addition to the problem of controlling hyacinths by chemical means and water weeds by mechanical means, considerable trouble is experienced from weeds and grasses along canal banks, i.e., "bankers". The principal offender in this regard is para grass which apparently is greatly encouraged to fast growth in canals near points of discharge of treated sewage effluent, sometimes growing

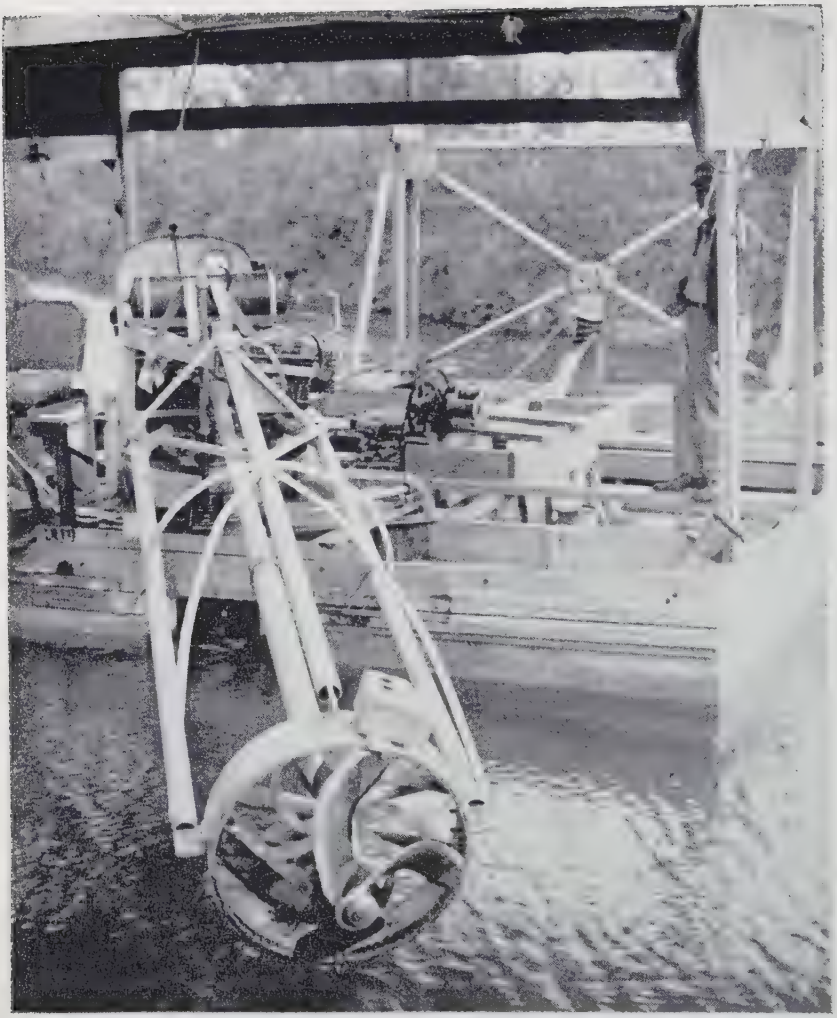

Figure 9.—Closeup of weedless wheel which creates suction for drawing weeds through propeller and chops weeds into small pieces. Boom is hydraulically operated, and rig moves from bank to bank by means of pipe spuds.

completely across the canal in a heavy mat which is difficult to remove even by dragline bucket because of the matted network formed by the growth. The elimination of this type of growth is being solved by dragging the channel with the duck, cleaning the bank by dragline, and experimenting with chemicals. The County's program has included almost constant use of small labor crews cutting along canal banks. In the Homestead area a small labor crew has been used to keep vegetation off the banks. Present usage also includes a mowing machine equipped for lowering the blade below the horizontal. A labor crew is also being used on small ditch-bank cleaning and for cutting smaller growth along

a few of the major canals. During flood periods considerable use of labor crews are also involved in cleaning operations around County dams and bridge piers. None of the costs of these operations are included herein. partly because of lack of time in which to prepare the data.

SUMMARY

The experience of the Dade County Water Conservation District in controlling water hyacinths and water weeds during the past five years may be summarized as follows:

1. About 194 miles of canals are patrolled (inspected) to detect reinfestation of water hyacinths. Repeated spraying of portions of 63 miles of these canals has been sufficient to control reinfestation. The field cost for hyacinth control has been $4.800 per year or about $76 per mile per year. (This is based on 2½ "rounds" or 157 work miles per year.)

2. About 40 miles of canals are being patrolled and 82 miles will soon be patrolled by amphibious duck to eradicate underwater weeds. During the past year, repeated dragging has been accomplished in the 40 miles of these canals at a total cost of $9.000 for the year, which is equivalent to $250 per mile of canal kept practically free of weeds during one year. (This is based on 4½ "rounds" or 180 work miles during the year.)

3. It is anticipated that hyacinths may eventually be eradicated in the eastern part of Dade County and that elimination of water weeds will become much less of a problem on major canals once greater depths have been excavated as planned by the Corps of Engineers and the Central and Southern Florida Flood Control District.

SYMPOSIUM: PLANT NEMATODES IN FLORIDA

MAINTAINING AND DETERMINING VIABILITY OF NEMATODES IN VITRO

Julius Feldmesser and William A. Feder *

Workers studying control of plant-parasitic nematodes and interested in a rapid assay of their results should consider the determination of nematode kill by direct microscopic examination and also the maintenance of the nematodes, removed from treated materials for examination under conditions which themselves do not affect the results.[1]

Direct visual examination is often the most practical method, especially when preliminary data or trends are desired. These examinations also serve to corroborate conclusions obtained by observations of symptoms on experimental plants.

Several general criteria useful in determining viability are described herein. The relative importance of these standards can best be evaluated only after the examination of many individual nematodes. They refer generally to the vermiform stages of plant parasitic nematodes and have been derived from observations made under the binocular dissecting microscope at magnifications ranging from 50 × to 75 ×.

The normal viable nematode, under these magnifications, presents a definite appearance. The stylet is plainly visible. The esophageal region, which may or may not be granular normally, shows no brownish or yellowish discolorations. The gut may or may not appear black, i.e., full. Nematodes use food materials stored in their guts until they reach plant tissues. These materials appear black. As the stored food is used, the gut may become vacuolated and when all of it is used, the gut may appear empty. A line of demarcation exists between the cuticle and the gut wall, i.e., the cylindrical gut lies within, but not touching, the cylindrical cuticle. Most variations from the normal, slightly crescentic position of the resting nematode are in smooth curves. Kinking seldom occurs. Movement may or may not be observed. When it does occur, it is rhythmic and coordinated.

Under the same magnifications, the injured, moribund or recently dead nematode presents a different aspect. The stylet may be obscured. The esophageal region may show brownish or yellowish discolorations. The gut may be vacuolated and granular or empty. If so, discoloration may be noted when light transmitted by the plane mirror is used. The line of demarcation between the cuticle and the gut wall may break down in some areas, i.e., adhesions between the cuticle and the gut wall may be

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[1] A second method, which will not be discussed here, is of a bio-assay nature. It involves growing plants or plants in treated soil areas. The effectiveness of nematode control is thereafter expressed in terms of plant yield and root and top symptoms, if any.

evident. The nematode may or may not be kinked. Lack of movement is an unreliable criterion. If movement is observed, it may be uncoordinated and jerky.

Dead nematodes show signs of decomposition and disorganization of soft inner structures.

Several techniques to corroborate diagnoses may be used. Living nematodes possess turgor. Dying or dead nematodes possess little or no turgor. Use may be made of this fact. When living nematodes are cut transversely with a needle or a scalpel, some of their inner structures and gut contents are ejected by the release of this inner pressure. When dying or dead nematodes are cut in the same manner, the body contents may ooze out slowly or may remain in place.

A second technique is that of artificial stimulation. This is accomplished by stroking the nematodes or turning them on their long axes on the bottom of the dish by means of fine, flexible picks applied to the region of the nerve ring in massaging motions. Such stimulation may induce independent movement by the nematodes.

Another technique involves alteration of oxygen tensions. Nematodes maintained in dishes filled with tap water or distilled water are soon subject to sub-optimal conditions. One of these conditions is thought by the authors to be an unfavorably low oxygen level, which causes marked reduction in nematode motility.[2] This has been borne out by inducing movement in previously immotile nematodes by the addition of oxygen by artificial aeration. Such aeration has been accomplished by washing the nematodes onto the disc of a Büchner funnel, flushing them several times with running water and then placing them in a dish of freshly aerated water.[3] Bubbling air through the stale medium also results in effective aeration.

An additional technique of use in laboratories equipped with an ultraviolet light source is one using acridine orange.[4] Under such light, dead nematodes appear red when stained with this dye and living nematodes appear green.

Workers concerned with the assaying of nematocides should bear in mind a complex of factors which may result in either the immobilization of nematodes or the extension of killing action beyond experimentally defined periods. It is thought that these factors include unfavorable oxygen and temperature relations and contamination by toxicants. Unfavorable oxygen tensions may be altered by aeration. Unfavorably high temperatures may result in accelerated metabolic rates of the nematodes under observation. They may also cause increased metabolic and reproductive rates of the bacterial, fungal, and protozoan contaminants. The resulting high levels of oxygen use and production of metabolic wastes may depress nematode activity and cause prematurely high death

[2] Feldmesser, Julius, and William A. Feder, 1954. Some effects of altered oxygen tensions on certain plant-parasitic and soil-inhabiting nematodes *in vitro*. Jour. Parasit. **40**: (5, Section 2):18.

[3] Feder, William A., and Julius Feldmesser, 1954. The use of the Büchner funnel as an aid in the concentration of nematode incula. Plant Dis. Reptr. 38 (12): 805-806.

[4] Homeyer, B., 1953. Die Unterscheidung lebender und toter Stockalchen (*Ditylenchus dipsaci* Kühn) durch Fluorochromierung mit Akridinorange. Nachrichtenblatt des Deutschen Pflanzenschutzdienstes **5** (1):8-11.

rates. These effects can be minimized by maintaining *in vitro* populations of nematodes at temperatures ranging from 40° to 50° F. during the intervals between examinations. Nematodes and nematode-infected plant materials treated with toxicants usually carry toxic residues. It is important that nematodes exposed to toxicants be washed free of excess amounts before being subjected to periodic microscopic assays. This procedure serves to confine the action of nematocides to known experimental periods.

THE STING NEMATODE, *Belonolaimus gracelis*, Steiner

A. N. Brooks *

Of the five nematode species thus far found attacking strawberry roots in the Plant City area the sting nematode is by far the most important. Although the culprit was not properly identified until the season 1949-1950 the root injury caused by some ectoparasitic nematode was definitely determined during the season 1946-1947. At that time it was incorrectly identified as the meadow nematode *Pratylenchus pratensis*. The description of the new species of nematode, *Belonolaimus gracelis* did not appear in print until some 2 - 3 years later.

The sting nematode is 2 to 3 mm. long and has such unique morphological characteristics that it can be readily identified under magnifications as low as 10 to 15x. Its movements in water are sluggish and somewhat sinuous. If specimens of this species are thoroughly washed and placed in clean water they can be kept viable for fairly long periods of time, 8 to 10 days at room temperature and as long as 3½ months at 35° F.

Our methods of collecting specimens of this nematode have changed from time to time depending upon the information desired. At first the unit consisted of the plant roots together with one quart of soil from the rhizosphere. Later this was reduced to one pint of soil. At the present time the plant roots are carefully removed together with what soil adheres to the root system. In this way there is less material to process by the sieving - Baermann funnel technique and yet the results are reliable in establishing the presence or absence of the nematode around the roots of the plants.

In the field, infested strawberry plants can be easily identified because of the cessation of growth and gradual decline in size. Edges of leaflets usually display a brown discoloration which gradually involves the entire leaflets, causing its death. The infested plant may die or may just linger on indefinitely in an extremely stunted condition.

The field picture is not one of uniformly infested fields, rather it is one in which there are circular or oval areas of stunted plants. As the season advances, these areas may enlarge in size as though the nematodes were migrating from plant to plant. However, it is doubtful that such migration actually takes place with a nematode as sluggish as the sting nematode. More likely, it is caused by a difference in density of population. Where population centers are most dense the plants are affected first. Then as the population in the area around the center builds up, the plants in those areas become affected. These initial density differences are due probably to different weed plants in the natural cover of fields during the summer. As yet there is not enough information on weed plants in relation to sting nematode development.

Of the natural cover plants, crabgrass has been found to carry the nematode over during the summer and even allow it to multiply. Of the leguminous crops, sesbania also favors the nematode. Fields of this species have been noted in which the pattern of dwarfed and normal

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plants was similar to that occurring in the strawberry fields. The sting nematodes were found on the roots of the stunted sesbania plants.

Of the vegetable crops grown in the Plant City area stunting due to sting nematode has been found in eggplant, in pepper to some extent, and in okra. Snap beans or pole beans grown on infested land have not shown definite symptoms.

Control by soil fumigation has proven of great value in infested land. Solid treatment is necessary for nursery fields but the row or bed treatment is satisfactory for fruiting fields and has a long lasting effect as far as the sting nematode is concerned. Soil is fumigated in September. plants set for fruiting in October and the last fruit is picked for market early in April; a total crop time of 6½ months. During the past summer a field of sesbania was examined, in which part of the field had been row fumigated with D-D the previous September. Sesbania plants in the treated area were normal in growth. In the remainder of the field there were large areas of stunted plants due to sting nematodes. The line of demarcation between treated and untreated soil was quite sharp. This showed that the soil fumigation had greatly reduced the population of sting nematodes in that area of the field and subsequently there did occur a rapid build up in numbers.

Although soil fumigation is quite successful in controlling sting nematode, I view it as a substantial crutch to lean upon. From some observations and experimental work during the past years I believe that much may be accomplished by certain cultural practices. Sting nematode has become important during the past ten years. This coincides with a decrease in the use of velvet beans as a summer cover and an increase in the use of sesbania. During the World War II many of the fields were more or less neglected and natural growth allowed to cover the land in the summer. The bulk of this natural growth was crabgrass. Sesbania and crabgrass allow a build up in population of sting nematodes. At present we do not know just what the relation is between the sting nematode and velvet beans.

Another small-sized experiment tended to show that populations of sting nematodes were decreased by rotary tillage. This cultural method breaks up dense populations and aerates the soil to the point where many nematodes are killed due to drying out. On the other hand the regular bottom plow turns over dense populations intact and does not aerate the soil.

It is to be hoped that in the near future we may be able to secure more information on the relation of cover crop plants, both cultivated and natural, to nematode survival and multiplication: also, the effect of certain cultural practices on reducing or building up populations of sting nematode.

RELATIONSHIPS BETWEEN PLANT PARASITIC NEMATODES, PATHOGENIC FUNGI, AND LADINO CLOVER YIELDS IN EXPERIMENTAL POT STUDIES

J. M. GOOD, JR., and W. G. BLUE *

INTRODUCTION

Soil fertility experiments conducted in the greenhouse for the purpose of obtaining leads for field investigations are widely used. Greenhouse conditions provide control of many environmental factors; i.e., light, temperature, moisture, and nutrient levels. Elaborate precautions are often taken to insure freedom from the confounding effects of these environmental factors on plant development.

The control of substrate factors other than nutrient levels may be of importance in reducing experimental error. One which may be of considerable importance in some instances is the nematode. This possibility was suggested by erratic data obtained by the authors from a phosphorus experiment in which Ladino clover, *Trifolium repens* L., was grown on Red Bay fine sandy loam. Typical data for three replicated phosphorus levels with $CaCO_3$ are shown in Table 1. Lower yields were associated with restricted root systems and brown necrotic lesions on the roots. Further examination established the presence of meadow nematodes in the soil in which the injured plants grew. Based on these observations, experiments were initiated to evaluate the influence of plant parasitic nematodes, and possibly other soil organisms, on experimental variability and injury to Ladino clover.

TABLE 1.—DRY WEIGHT YIELD VARIABILITY AND ROOT CONDITION OF LADINO CLOVER FROM A SOIL FERTILITY STUDY WITH RED BAY FINE SANDY LOAM.

Treatments	200 Lbs. P_2O_5 + $CaCO_3$		300 Lbs. P_2O_5 + $CaCO_3$		1,000 Lbs. P_2O_5 + $CaCO_3$	
Replication	I	II	I	II	I	II
Yield gms./pot	17.9	28.6	17.1	26.3	28.6	32.3
Root condition	poor	good	poor	good	poor	good

In the past, various plant-parasitic nematodes have been reported on white clover, but only in a few cases has any appreciable damage been noted. In 1905 Sheldon (8) recognized root-knot nematodes on *T. repens*. Some twenty years later Goodey (5) and Ware (10) reported the stem nematode, *Ditylenchus dipsaci* to be a destructive parasite of white clover.

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A cyst nematode *Heterodera* sp. (3) and the leaf nematode *Aphlenchoides fragariae* (4) have also been found on white clover. Chapman (1) has recently found alfalfa to be severely injured by meadow nematodes. The number of eggs, larvae, and mature worms which he found indicates that alfalfa must be a favorable host for the reproduction of these nematodes.

MATERIALS AND METHODS

EXPERIMENT I. Pots of Red Bay fine sandy loam which had been used in the phosphorus experiment were left in the greenhouse from July to October 1952. No water was added and the temperature regularly exceeded 120° F. On October 9, 1952, this soil that had previously harbored the smooth-headed meadow nematode, *Pratylenchus brachyurus* [syn. P. *leiocephalus* (9)] was screened and thoroughly mixed. Ten two-gallon pots were filled with moistened soil and fumigated with one pound of MC-2 in a fumigation box for 40 hours. To insure better diffusion of the MC-2, a central hole approximately one inch in diameter was made in the soil in each pot. Following fumigation these pots were allowed to aerate for eight days; after this period there was no odor of the fumigant. In addition, 10 two-gallon pots were filled with the untreated soil for controls. All pots were seeded with inoculated Ladino clover, fertilized at a rate equivalent to 100 pounds per acre with calcium sulfate and potassium chloride, and then placed in the greenhouse so that the controls were adjacent to the fumigated pots. On November 10 the plants were thinned to ten per pot. The plants in the MC-2 treated pots did not nodulate, while those in the control pots were well nodulated. All plants nodulated after reinoculation. The clover was clipped five times, and the clippings were oven dried at 70° C. for yields. Following each clipping potassium sulfate in aqueous solution equivalent to 100 pounds per acre was applied to each pot. In June the pots were placed in a partially-shaded spot outside the greenhouse. On June 10 a 150-cc. composite soil sample was taken from each pot for nematode studies. The nematodes were removed from the soil by use of a combination of sieves (retaining sieve was 200 mesh) and the Baermann funnel (2). Nematodes were removed from the funnel after 24 hours and counted. Root samples were examined for nematodes and indications of disease.

EXPERIMENT II. Sixty gallons of Arredondo fine sand were fumigated with 240 ml. of D-D in a sealed oil drum. After one week the soil was spread in a one and one-half inch layer on a greenhouse bench and allowed to aerate for three weeks by periodically mixing. Potassium chloride was mixed with the soil at a rate equivalent to 100 pounds per acre. On March 4, 1954, 20 two-gallon pots of this soil were seeded with inoculated Ladino clover seed. A poor stand was obtained, and these pots were replanted on April 6. On May 4 the plants were thinned to five per pot. A randomized design with four treatments and five replications was used. The treatments consisted of inoculations with (a) sting nematodes, (b) sclerotinia rot fungi, (c) sting nematodes and sclerotinia rot fungi, and (d) check with no added organisms.

The sting nematodes, *Belonolaimus gracilis*, had been cultured in a Bermuda grass flat. Nematode inoculants were obtained by removing them from the soil by the method described by Christie and Perry (2), allowing the contents of the funnel to drain over a 100 mesh screen, and

washing the screen with a water spray to separate small nematode species from the larger sting nematodes. For the nematode treatments, the soil in each pot was inoculated with approximately 1,000 sting nematodes. The inoculants contained in addition to sting nematodes occasional specimens of *Dolichodorus heterocephalus* and saprophytic nematodes. Each *Sclerotinia sclerotiorum* inoculant was a 25 ml. distilled water suspension of six-day old minced mycelia from agar slants.[1]

On July 1 the pots were removed from the greenhouse and placed in the identical location that had been occupied by the pots of Experiment I. The pots were clipped four times between June 1 and September 23, 1954, and oven dry weights determined. These pots received potassium sulfate equivalent to 100 pounds per acre following each clipping. Five one-inch plugs of soil taken to a depth of six inches were composited, and a 150 cc. sample was taken for nematode studies. The nematodes were isolated and counted in the same manner as in Experiment I.

Figure 1.—June, 1953. Pot on left: Fumigated with MC-2. Pot on right: Check containing *P. brachyurus* and *S. sclerotiorum.*

RESULTS

Experiment I. Examination of yield data in Table 2 indicates that mean differences between MC-2 treatments and the checks were highly significant, except for the second clipping. At the first clipping, the MC-2 treated pots had lower yields than the checks; however, the third, fourth and fifth clippings from the treated pots gave larger yields than the checks. With this reversal the coefficient of variability for yields within

[1] Dr. Phares Decker, Plant Pathologist, Agricultural Experiment Station, identified the fungus referred to in this paper and supplied the inoculant.

the fumigated treatment for the fourth and fifth clippings became smaller than that of the checks. Yields from the check pots progressively declined during the spring and summer (Fig. 1, 2). The plants from check pots exhibited loss of vigor, reduction of leaf size, and yellowing of leaves. By August one of the check pots contained no living plants, and plants in the others were not growing (Fig. 2).

Figure 2.—August, 1953. Pot on left: Fumigated with MC-2. Pot on right: Check containing *P. brachyurus* and *S. sclerotiorum*.

Microscopic examination of the roots showed extensive necrosis, sluffing of the cortex, and few healthy nodules. Numerous smooth-headed meadow nematodes, *Pratylenchus brachyurus*, were present in the brown, necrotic lesions. In addition, sclerotia of *S. sclerotiorum* were present on the roots of diseased plants. The 150 cc. soil samples from around the clover roots of the non-fumigated pots contained an average of 82.9 meadow nematodes (Table 2) and several species of saprophytic soil nematodes. In contrast to the non-fumigated pots, the fumigated pots contained only an occasional soil nematode.

The root systems from the fumigated pots were well developed and free from infection. Yields declined slightly during the hot summer months (Table 2); however, during August, when plants in the non-fumigated pots were practically non-existant, those in the fumigated pots were relatively vigorous (Fig. 2). In all treatments plants that had not died began to show new growth with the onset of lower temperatures in early November.

Experiment II. During June and July few differences could be detected among treatments (Table 3). After the third clipping, however, plants in all replications treated with sting nematodes grew slower than

TABLE 2.—THE EFFECT OF MC-2 FUMIGATION ON LADINO CLOVER YIELDS, MEADOW NEMATODES, AND COEFFICIENT OF VARIABILITY FOR TEN FUMIGATED AND TEN NON-FUMIGATED POTS.*

Treatment	Yield					Meadow Nematodes
	January 20	March 25	April 24	June 10	August 9	June 10
MC-2						
Range	2.5-5.8	11.4-17.1	21.6-23.6	12.3-16.6	10.8-13.4	1-4
Average	4.2	14.4	22.8	14.6	12.2	0.7
Coef. Var.	27.5%	12.7%	2.6%	11.1%	6.1%	
Check						
Range	6.7-8.6	12.4-14.9	14.5-21.0	7.8-12.5	0.0-3.2	23-208
Average	7.8	13.6	16.9	9.6	1.5	82.9
Coef. Var.	8.8%	6 3%	1.3%	13.4%	71.9%	
Sig.	**	non sig.	**	**	**	**

* The yield data for the five clipping dates are expressed in gms./pot on an oven dry basis. Meadow nematode counts were made on an 150 cc. soil sample from each pot.

TABLE 3.—THE EFFECT OF STING NEMATODES AND *Sclerotinia sclerotiorum* ON YIELDS OF LADINO CLOVER.*

Treatments	Yield			
	June 1	July 1	August 12	September 23
Check				
Range	10.6-12.8	12.8-17.0	27.5-32.4	6.5-17.2
Average	11.6	15.8	29.5	12.3
Sting Nematode				
Range	7.8-12.4	11.3-17.6	20.1-32.0	0.1- 5.4
Average	10.5	15.7	24.7	3.0
Sting nematode + *S. sclerotiorum*				
Range	10.6-13.2	10.0-17.6	19.0-24.5	0.2- 2.8
Average	12.3	15.2	21.9	0.7
S. sclerotiorum				
Range	10.9-13.6	14.5-17.9	23.0-32.1	8.2-10.5
Average	12.1	16.4	28.6	9.6
L.S.D. .05	N.S.	N.S.	4.0	3.3
L.S.D. .01	N.S.	N.S.	6.0	4.6

* Yields are expressed in gms./pot on an oven dry weight basis. Each treatment was replicated five times.

those in the checks and those with *S. sclerotiorum*. Yields from the third and fourth clippings were significantly lower for all pots containing sting nematodes; *Sclerotinia* tended to reduce the yields when it was the only disease organism present or when it coexisted with the sting nematode. Lowest yields were obtained in the treatment where both *B. gracilis* and *S. sclerotiorum* were present (Fig. 3).

Figure 3.—Effects of four treatments on Ladino clover: (A) Check. (B) Sting nematode. (C) Sting nematode and *S. sclerotiorum*. (D) *S. sclerotiorum*.

Examination of the soil for nematodes on September 23 showed an average of 40 sting nematodes per 150 cc. of soil in the treatments which had originally received nematode inoculations. An occasional awl nematode was found. Few immature sting nematodes were seen, and the intestines of the mature worms contained little food. Two check pots which became contaminated contained 155 and 251 sting nematodes. In both cases there were many immature nematodes. and the intestines of the mature worms were filled with food material. By early November plants in these two pots began to decline. No parasitic nematodes appeared in the *S. sclerotiorum* treatments.

Microscopic examination of the clover roots from sting nematode treatments revealed extensive stubbing, typical of the injury commonly produced by this nematode on many other plants. Small necrotic lesions and sclerotia were more numerous in the treatments that received sting nematodes and *S. sclerotiorum*. Check plant roots were practically free of necrotic lesions; however, a few sclerotia were observed.

The growth in all but three pots markedly increased in early November. Clover did not survive after the last clipping on one pot where only sting nematodes were added and two others where both nematodes and *Sclerotinia* were present.

DISCUSSION

In both experiments some difficulty was experienced in obtaining nodulation following fumigation. In Experiment I the time was not sufficient for diffusion of MC-2 from the Red Bay fine sandy loam. To overcome this difficulty, the soil used in Experiment II was allowed to aerate for a longer period. After three weeks the odor of D-D could still be detected. Poor diffusion of D-D from soil that has been allowed to dry following fumigation has been observed on several occasions. Yield data from both experiments indicate that several weeks were needed for the residual fumigant to disappear. Also, several months were apparently necessary for the nematode population to acquire damaging proportions, even when 1,000 sting nematodes were added to each pot. In short term experiments or when resistant host plants are grown, nematode damage is probably of less importance in experimental variability than in those of long duration.

Even though the necrotic lesions on Ladino clover roots in Experiment I were typical of meadow nematode injury observed on other plants, the coexistence of *Sclerotinia* in the non-fumigated soils may have been a contributing factor to the severity of root damage and increased experimental variability. This association of nematodes and phytopathogens in disease complexes of plants is being given more consideration in economic crop production. Some of the more important aspects of this problem have been recently summarized by Holderman (7). In a study of several agricultural plants, one of which was red clover, Hastings and Bosher (6) observed that plant injury was greater where the meadow nematode *P. pratensis* and the fungus *Cylindrocarpon radicicola* coexisted than when only *P. pratensis* was present.

Results of Experiment II indicate that the sting nematode is capable of causing root injury on Ladino clover but the injury reflected in yields was only slightly greater when the fungus *S. sclerotiorum* was associated with the sting nematode. In both experiments *S. sclerotiorum* appeared to be of little importance in the disease complex of Ladino clover.

The sting nematode counts from Experiment II were not large; however, the population had probably declined before counts were made because of a decrease in food material. This assumption was substantiated by the presence of few immature nematodes in the soil around the roots of injured plants and the presence of many immature nematodes in the two check pots that had become contaminated with sting nematodes. In the latter case, there was an adequate food supply for an actively reproducing nematode population. Vegetative evidence of injury did not occur in these plants until the middle of November, 1954.

During the late summer of 1953 and 1954, the yields and plant densities abruptly declined in all cases where plant parasitic nematodes were present. The presence of pathogenic fungi slightly accentuated this condition. During the same period, healthy clover plants showed only a slight reduction in yield.

CONCLUSIONS

Experimental variability was reduced by soil fumigation in greenhouse pot studies where plant parasitic nematodes and pathogenic fungi were present in the soil. The meadow nematode *Pratylenchus brachyurus*

is capable of reestablishing itself after exposure to several months of storage at high temperature in dry soil. Ladino clover yields were reduced and plants were severely injured by the sting nematode *Belonolaimus gracilis*, and yields were slightly reduced when *Sclerotinia sclerotiorum* was associated with the sting nematode.

A progressive reduction in yields and plant densities during the late summer was found to be associated with plant parasitic nematodes and to a lesser extent with *S. sclerotiorum*. Ladino clover from the check treatments remained relatively vigorous during the same period.

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NEMATODES ASSOCIATED WITH INJURY TO TURF

J. R. Christie, J. M. Good, Jr., and G. C. Nutter *

During the past few years attention has been directed to the fact that nematodes are responsible for some of the difficulties experienced in maintaining turf. In 1951, Tarjan and Ferguson (2) investigating the cause of a diseased condition of bent grass in Rhode Island known as "yellow turf", concluded that certain nematodes found in or associated with the roots of the grass may have been a contributing factor. In a recent paper, Troll and Tarjan (3) report the results of a survey of 41 putting greens from 17 different golf courses in different parts of Rhode Island where the turf showed symptoms of chlorosis or of die-back of grass blades. Of the various kinds of nematodes found associated with the grass roots, ten were regarded as known plant parasites. Of these, the stunt nematodes, *Tylenchorhynchus* spp. were found most frequently and in greatest numbers.

Erdman West, who has had occasion to examine samples of unthrifty turf sent in for diagnosis from various parts of Florida, was one of the first to suspect that part of this damage was due to nematodes. Kelsheimer and Overman (1) investigated lawn grass failures in the Tampa Bay area that did not appear to be attributable to chinch bugs, lack of fertilizer, or unfavorable soil conditions. They found various plant nematodes associated with injury to the roots of St. Augustine grass and Bermuda grass, including the sting nematode, *Belonolaimus gracilis;* a stubby-root nematode, *Trichodorus* sp.; ring nematodes, *Criconemoides* spp.; the crown-headed lance nematode, *Hoplolaimus coronatus;* a bulb and stem nematode belonging to the *Ditylenchus dipsaci* complex; and even the burrowing nematode, *Radopholus similis.* When the sting nematode or the stubby-root nematode was present, the roots of the grass plants frequently showed the "stubby-root" type of symptom charactertistic of the injury caused by these external feeders.

Obviously, nematode injury to turf in Florida is not a simple problem involving only one or a few species of these parasites. Nearly every root-injuring nematode known to occur in the state has been found, at one time or another, associated with injury to roots of lawn grasses. Furthermore, there appears to be seasonal variations in the relative abundance of the different species involved.

Results from an examination of 60 turf samples, collected in various parts of the state, will serve as an indication of the general situation. Of these 60 samples, 22 were of St. Augustine grass, 17 were of centipede grass, 15 were of Bermuda grass and 5 were of Zoysia grass. The sting nematode was present in 36 samples and was numerous in 18; the crown-headed lance nematode was present in 27 samples and numerous in 13; ring nematodes were present in 20 samples and were numerous in 4;

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spiral nematodes, *Rotylenchus* spp., were present in 10 samples and were numerous in 1; stubby-root nematodes were present in 10 samples and were numerous in 2; stunt nematodes were present in 5 samples and were numerous in 2; dagger nematodes, *Xiphinema* spp., were present in 4 samples and were numerous in 2; the awl nematode, *Dolichodorus heterocephalus*, was present in 2 samples and was numerous in 2; meadow nematodes, *Pratylenchus* spp., were present in 5 samples but were numerous in none; and *Hemicycliophora* sp. was present in 3 samples but was numerous in none. In collections made by Mrs. Overman in the region of Bradenton, spiral nematodes were the predominating kind, occurring in 62 out of a total of 74 samples.

In view of these observations, it appears that the sting nematode, the crown-headed lance nematode, and one or more species of spiral nematodes are responsible for most of the nematode damage to turf in Florida, with ring nematodes, stubby-root nematodes, stunt nematodes, and the awl nematode causing damage occasionally.

The sting nematode is an external parasite that feeds at root tips and along the side of succulent roots. The root systems of affected plants have abnormally few small rootlets; those that occur are abnormally short, sometimes almost knob-like. This "stubby-root" type of symptom is more noticeable on grasses with large roots like St. Augustine than on those with small roots like Bermuda. St. Augustine, centipede, Bermuda and probably Zoysia are all about equally susceptible to injury but certain strains of Bermuda may be somewhat less susceptible than others.

The crown-headed lance nematode is very common in Florida and obviously feeds on many different kinds of plants. It may feed largely from the outside by embedding the anterior end of the body or it may enter a root completely. It is probably the largest of the internal parasites of roots; when it feeds in this manner it causes very extensive destruction of the root tissues. Observed instances of severe damage to turf have been confined largely to St. Augustine grass, but the other grasses are damaged, at least to some extent. Dead roots from which the outer layers slough off easily seems to be the most characteristic symptom of injury.

The spiral nematodes are, for the most part, external feeders that embed only the anterior part of the body, although they may sometimes enter the roots. They are much smaller than the lance nematodes which they otherwise resemble. Several species have been found associated with injury to turf, the identities of which have not yet been fully established. *Rotylenchus multicinctus*, or a form closely related to it, has been encountered frequently and the one found most often in the Bradenton area seems to be an undescribed species. The spiral nematodes have not been studied very much. Not enough is known about them to properly evaluate their importance or the extent of the damage they are capable of causing. Circumstantial evidence indicates that they initiate injury which in some instances, may become very extensive.

Stubby-root nematodes probably are somewhat more common in Florida turf than the above records indicate. When present in appreciable numbers they are capable of causing serious damage.

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USE OF NEMATOCIDES ON ESTABLISHED TURF

A. J. Overman *

Florida has a large annual investment in its lawn and turf grasses. Thrifty, attractive turfs are the goal of every home owner, greenskeeper and institutional groundskeeper. Proper recommendations for use of water, plant foods, fungicides and insecticides have been developed to alleviate some common problems of maintenance.

In recent years, however, a new pest has been recognized—the parasitic nematode. Because nematodes are usually insidious enemies, symptoms of their damage in the past have probably been attributed to various mineral deficiencies or inadequate soil moisture. Since 1952, numerous observations (1) have been made of damaged turf on which the maintenance practices were considered adequate, and on which no response was obtained from additional applications of fertilizer, fungicides or insecticides. Investigation led to the identification of large populations of parasitic nematodes in the soil where lawn grasses such as Everglades Bermuda No. 3, St. Augustine and Zoysia matrella were in decline. In the *Phasmid* Subclass members of the Family *Tylenchidae* were found: *Ditylenchus* sp., *Hoplolaimus coronatus*, *Radophalus similis*, *Criconemoides* sp. and *Belonolaimus gracilis*. Numerous specimens of the *Aphasmids*, *Trichodorus* sp, and *Xiphenema* sp. also appeared in various areas.

These high populations were usually associated with dead patches in the turf, while the surviving grass showed stunting and a yellow color. It was found that the roots of affected plants were browned and matted, often possessing numerous rootlet proliferations above dead root tips. These conditions of limited root efficiency could account for the various defiicency symptoms visible on the above-ground portions of the grass.

Control measures against the nematode are complicated by the fact that nematocides in use today are phytotoxic at effective rates, thus prohibiting their application to established turf. Preliminary small tests indicated that two materials recently released for experimental purposes might be less phytotoxic than the standard nematocides. Since good plant response was obtained in various observational trials, a carefully designed experiment was planned to compare the effects of the materials on nematode populations and grass development. The materials chosen for test were: VC 1-13 (*O*-2,4-Dichlorophenyl *O*, *O*-diethyl phosphorothioate),[1] and Nemakril (β-propiolactone derivative).[2]

In September 1954 these materials were compared on plots, each containing 50 square feet, on an infested fairway of the Bobby Jones Municipal Golf Course in Sarasota, Florida. Golf course fairways are usually low-maintenance areas which support a combination of grasses and weeds. The trial ground was chosen for its uniformity of plant

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[1] Virginia-Carolina Chemical Corporation.

[2] The B. F. Goodrich Company.

distribution, consisting primarily of St. Augustine, Bermuda, and Oxalis. On two replications a medium thatch had developed, but the two replications on higher ground were more sparsely covered. Although the soil was well compacted, drainage was good. Preliminary determinations established the fact that nematodes were greater in number on the high ground, with the same types represented as in the lower area.

Since the labor involved in drench treatments is far less than in applications made by staggered 12-inch injections, each material was compared under both methods of treatment. Approximately 850 gallons per acre of water was used where the chemicals were drenched into the turf with a hose attachment. An injection gun was used for the spot treatments. Two rates of each material were included: 15 and 30 gallons per acre. Four complete replications of all factors were treated on September 15. Immediately after treatment and twenty-four hours later one-half inch rainfalls occurred; these afforded a water seal for the injected chemicals.

There are problems to be met in obtaining uniform distribution of fumigant either by drench or injection. Old, established turf is often accompanied by a closely packed soil—this may inhibit the penetration of the drench or diffusion of volatile liquids released at a point 6 inches below the soil level. Also, a thick mat of organic matter or thatch may cover the soil surface, making it difficult to wash the fumigant to any appreciable depth.

Evaluation of nematocidal properties was made on the basis of comparable numbers of nematodes extracted from the soil by the modified Baermann technique before treatment, and two and eight weeks after treatment (Table 1). At the time of treatment, there was an abundance of recognized parasitic nematodes in the area. A spiral nematode (*Rotylenchus* spp.) was most prevalent, accompanied by numbers of sting (*Belonolaimus gracilis*), lance (*Hoplolaimus coronatus*), dagger (*Xiphenema* sp.) and various nematodes of the dorylaimid group. At present there is a seasonal decline in numbers measurable in the check areas which confounds the decreases due to nematocidal treatment, but moderate numbers of the spiral nematode survived in the untreated areas. It is not known how much damage these parasites may cause on the grasses, but their continued existence demonstrates the fact that they are obtaining food from the living roots of at least one of the plants present.

Eight weeks after treatment, Nemakril had drastically reduced nematode populations whether it had been drenched on the soil surface or injected. Results were as good with the 15-gallons-per-acre application as with the higher 30-gallons-per-acre rate. VC 1-13 was efficient when injected, but lowered populations were recorded in the drenched plots only where a heavy thatch had not developed. The drench apparently was not thoroughly washed through the mat on the surface to an adequate depth in the soil. In this season, small visual effect has been evident. In the treated areas some healthy, new roots are forming.

It is not expected that turf treatment can be a "one-shot" protection against nematodes. At best, such an operation decreases populations in the upper eight to ten inches of the soil and that area is soon infested from the outside. Since neither of the materials has shown any phytotoxicity, a program of routine fumigation for nematode control will be

TABLE 1.—RATINGS OF NEMATODE POPULATIONS BASED ON SOIL EXTRACTS.* AVERAGE OF FOUR PLOTS.

	Rate Gal./A.	*Rotylenchus* spp.	*Hoplolaimus coronatus*	*Belonolaimus gracilis*	*Xiphenema*	Dorylaimids in General	*Hemicyclophora*
				Before Treatment			
Drench VC 1-13	15	4.0**	1 0	1.0	0	1.0	0
	30	3.0	1.5	0	0	2 5	0
Nemakril	15	2.5	1.0	0	0	1 5	0
	30	4.0	0	0	1.0	2.0	0
Injection VC 1-13	15	3.0	0	0	1.5	3.5	0
	30	2.0	1.5	0	0	2.0	0
Nemakril	15	3.0	2.0	0	0	3.0	0
	30	3.0	.5	.5	0	2.5	0
Check		2.5	.5	0	.5	3.0	0
				Two Weeks After Treatment			
Drench VC 1-13	15	2.5	.5	.5	0	0	1.8
	30	2.5	.5	.2	0	0	.5
Nemakril	15	2.0	.2	0	0	0	0
	30	1.0	0	0	.2	0	.2
Injection VC 1-13	15	2.5	.2	0	.2	0	.2
	30	1 2	0	0	0	0	0
Nemakril	15	1.8	1.0	0	0	0	.5
	30	1.5	0	0	0	0	.8
Check		3.0	1.0	.5	1.0	0	0
				Eight Weeks After Treatment			
Drench VC 1-13	15	1.7	0	0	0	0	0
	30	1.0	.3	0	0	0	0
Nemakril	15	.3	0	0	0	0	0
	30	.3	0	0	0	0	0
Injection VC 1-13	15	.5	0	0	0	0	0
	30	.4	0	0	0	0	0
Nemakril	15	.3	0	0	0	0	0
	30	.3	0	0	0	0	0
Check		2.5	.5	0	0	0	0

* Identification with aid of Dr. J. R. Christie, Nematologist, Florida Agricultural Experiment Station, Gainesville, Florida.

** Rating Index: 0.—None. 1.—1 - 10 specimen. 2.—10 - 100 specimen. 3.—100 - 500 specimen. 4.—500 - 1,000 specimen.

followed. To effect a lasting protection for established plants these plots are to be maintained throughout the year to determine the practicality of applying fumigants three times annually in the same way as a fertilizer program is carried out. In this way it is hoped to discourage the build-up of parasitic populations during the dry seasons in high value turfs and allow the grasses to develop during the growing period unhampered by nematodes.

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A PRELIMINARY REPORT ON NEMATODE CONTROL IN A TURF MAINTENANCE PROGRAM

P. M. Ritty *

The nematode problem in Florida turfs is a recognized one. Control of nematodes in an established lawn without injury to the lawn has been impossible with presently available nematocides.

In basic phytotoxic studies with experimental compounds, the Research Dept. of B. F. Goodrich found a chemical that was relatively non-phytotoxic even though applied at concentrations sufficiently high to be nematocidal. Turfs of common Bermuda, Tifton-57 Bermuda, St. Augustine and Centipede grasses were treated with the experimental chemical in concentrations high enough to reduce pathogenic nematode populations without apparent injury to the grasses.

In order to more thoroughly test this experimental compound, which is a derivative of beta-propiolactone and hereinafter referred to as Nemakril, a bowling green in Sarasota, Fla., was selected as a test site. The turf, consisting of common Bermuda, had been in a serious state of decline and was responding to neither fertilizer nor lime applications. Soil samples disclosed moderate to heavy populations of *Belonolaimus gracilis*, *Hemicycliophora* sp., *Helicotylenchus* sp., and *Hoplolaimus coronatus*. Large areas of the green contained no live turf and were being invaded by spotted spurge and goose grass.

If the belief that permanent nematode control cannot be accomplished in one application is correct, then nematocides will eventually have to be considered a part of turf maintenance just as are fertilizers and insecticides at the present time. This study was designed to investigate the possibility of the inclusion of a nematocide into a regular turf management program.

One entire bowling green was to be treated with Nemakril three times over the period of one year at 4-month intervals. The regular maintenance of the green, as conducted prior to nematocide applications, was to be continued for the duration of test.

The first application of Nemakril was applied on May 14, 1954. The total area treated was 14,400 sq. ft. Method of application was by injection to a depth of 6 inches and at 12-inch intervals. A total of 24.2 gallons per acre was applied.

The maintenance program of the green from the time of first nematocidal treatment is as follows:

June 7, 1954: The green was hand weeded and top-soiled lightly.

June 12, 1954: The total area fertilized with 500 lbs. of a 6-6-6 fertilizer plus 500 lbs. of dolomite.

June 22, 1954: Five weeks after treatment and 10 days following the above mentioned fertilizer application the bowling area exhibited regreening remarkably. New Bermuda grass runner growth was readily

* The B. F. Goodrich Co.

apparent. Interestingly enough, a similar fertilizer application to the area 2 months before treatment with the experimental nematocide had produced no visible regreening. Moreover, an adjacent green not treated with the nematocide but receiving identical fertilizer application on June 12 was showing turf decline symptoms at this time.

July 7, 1954: Soil samples were taken from the treated green with the following findings: Of the sting, spiral, lance and *Hemicycliophora* spp. found before nematocide treatment, slight numbers of all four spp. were still present. In a letter from Mrs. A. J. Overman, Soil Scientist, Gulf Coast Expt. Sta., Bradenton, Fla., to whom the author is indebted for nematode analysis and identification, she stated, "The Nemakril treated area was very low in nematode population even though so many kinds were present . . . those present may or may not indicate that the treatment did or did not give total kill. The nematodes may have come up from below, following the food supply." [1]

July 28, 1954: Eleven weeks after Nemakril application, extensive regrowth of grass into previously denuded areas was occurring while the adjacent untreated bowling green was in a serious state of decline.

Sept. 13, 1954: Treated green was hand-weeded, fertilized with 500 lbs. of 6-6-6 fertilizer and top soiled.

Sept. 14, 1954: Soil samples taken showed moderate numbers of *Hoplolaimus coronatus* and a *Hemicycliophora* sp., and an average number of *Rotylenchus* and *Helicotylenchus* spp. All species populations were less than originally found prior to nematocide treatment four months earlier.

On this date also, the green was given a second application of Nemakril. This application differed from the original treatment in that it was applied by drenching on the surface. A garden hose aspirator attachment was used to syphon the nematocide into the spray stream. No emulsifier was used. The treated area was then watered thoroughly to provide a water seal and distribute the Nemakril into the root area.

Sept. 30, 1954: Soil samples from the treated area showed mostly saprophytic nematodes present. A very few *Rotylenchus* sp. were found, but no other known pathogenic nematodes were present.

Oct. 4 - 8, 1954: Approximately 1,000 sq. ft. of sod was plugged into areas on the green from which spotted spurge and goose grass had been weeded.

Oct. 8, 1954: The green received 400 lbs. of 4-7-5 fertilizer.

Nov. 8, 1954: Additional soil samples were screened and results showed a very few dagger nematodes (*Xiphenema* sp.). Most nematodes found were saprophytic spp.

In summary, indications from this test now being conducted on the bowling green in Sarasota, Fla., seem to give some hope that a chemical has been found which, under the conditions of the test, is apparently non-phytotoxic to established common Bermuda grass. Moreover, a measure of nematode control has been obtained over a period of six months which, while not completely eliminating pathogenic nematodes, has depressed their populations to the level where the turf can flourish in spite of their remaining numbers.

[1] Letter Overman to Ritty 7-6-54.

The experimental chemical used in this test is presently being tested on other types of turfs in Florida and Georgia. Of necessity the information presented in this paper is limited. However, with additional cooperative investigations by nematologists in the Southern States, perhaps a more complete picture can be presented in the near future.

NEMATODES ASSOCIATED WITH CITRUS IN FLORIDA

E. P. DuCharme and R. F. Suit *

In the course of our studies on spreading decline of citrus, caused by the burrowing nematode, *Radopholus similis* (Cobb) Thorne 1949, we found 12 other species of plant parasitic nematodes associated with roots of both healthy and diseased citrus. Whereas none of the 12 species can be implicated as a primary cause of spreading decline, some of them may be potentially important parasites of citrus. Consequently, it is worthwhile to summarize some of the information concerning the prevalence of these nematodes in groves, and to discuss the present state of knowledge regarding their importance to citrus in Florida.

Since all 13 species of nematodes found associated with citrus roots in Florida (Table 1) are free living, or spend at least part of their life cycle migrating from one root to another, it was possible to extract them from soil-root samples by the sieve and Baermann funnel technique (7). However, to determine whether or not they are endoparasitic it was necessary to dissect them from infested rootlets and incubate them from washed rootlets held in closed pint jars for three or more days.

Four of the 13 species listed in Table 1 have been previously reported as being associated with citrus in other parts of the world. Twelve of the species have been found in areas of spreading decline but only *Radopholus similis* (Cobb) is either common to or confined to such areas. *Hexatylus* sp. Goodey has not yet been found in an area affected by spreading decline. The number of healthy groves in which these nematodes have been found is of little significance except for *R. similis* and *T. semipenetrans* (Cobb) because relatively few healthy groves have been carefully inspected for presence of the other species.

The burrowing nematode, *Radopholus similis* (Cobb) Thorne 1949, causes spreading decline, at present the most dreaded disease of citrus in Florida. The disease was known to be present in the state as early as 1930, but its etiology remained an unknown quantity until 1953. At that time, sufficient experimental evidence became available to demonstrate that *R. similis* is the primary causal agent (4 and 9). To date, this nematode has not been found on citrus outside Florida. Burrowing nematodes parasitize citrus by penetrating the feeder roots, thus initiating rootlet destruction which eventually leads to decline of the trees. A typical spreading decline area consists of a group of trees all of which have the same non-thrifty appearance. The trees are stunted, have undersized leaves, sparse foliage, reduced terminal growth, lowered yields, and extensive deterioration of the feeder-root system below a depth of about 20 inches. Such trees remain in a decline condition indefinitely but are not killed by this disease. What distinguishes this from other declines is the fact that the area spreads continuously and about equally in all directions regardless of elevation or direction of rows and cultivation. This constant spread in all directions is one of the most characteristic

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features of this disease, which has been found in more than 400 grove properties and 35 citrus nurseries. The burrowing nematode is, however, not restricted to citrus but has a wide host range (1). It is spread from nurseries to groves when infested trees and ornamental shrubs are planted in groves or adjacent areas.

TABLE 1.—NUMBERS AND TYPES OF 255 CITRUS GROVES EXAMINED, IN WHICH 13 SPECIES OF PLANT PARASITIC NEMATODES HAVE BEEN FOUND.

Nematodes	Spreading Decline Affected Groves		Healthy Groves Only	Decline Area Not Spreading Decline		Total Number of Groves
	Decline Area	Healthy Area Only		Decline Area	Healthy Area Only	
Radopholus similis (Cobb) Thorne	147	0	0	0	0	147
Tylenchulus semi-penetrans Cobb	13	2	13	18	1	47
Belonolaimus gracilis Steiner	16	1	6	14	0	37
Hoplolaimus coronatus Cobb	37	0	6	12	1	56
Pratylenchus pratensis (de Man), Filipjev	21	5	8	13	0	47
Aphelenchus avenae Bastian	68	2	18	20	1	109
Trichodorus sp. Cobb	26	3	5	9	0	43
Xiphinema americanum Cobb	1	3	11	3	1	19
Hemicycliophora sp. de Man	2	0	0	6	0	8
Criconemoides citri Steiner	26	1	1	11	0	39
Rotylenchus sp. Filipjev	2	0	0	3	0	5
Hexatylus sp. Goodey	0	1	0	0	0	1
Aphelenchoides sp. Fischer	1	0	0	0	0	1

The citrus nematode, *Tylenchulus semi-penetrans* (Cobb) 1913, was found infesting citrus roots in Florida by Byars in 1913 (2). This nematode is also an important parasite on citrus roots and causes a non-thrifty condition of trees in severely infested groves, yet trees often support large numbers of citrus nematodes without showing obvious symptoms of disease. Centers of infestation are poorly defined and spread is very slow. The female citrus nematodes are sedentary in habit, being partially imbedded in the rootlet cortex with the posterior portion of the body remaining free of the rootlet. The adult males, as well as larvae of both males and females, are free living in the soil but remain close to the rootlet. Thus far, citrus nematodes have been found in 47 groves in 15 counties where citrus is grown. Thirteen of these groves were affected by spreading decline, 18 had some other type of decline and 13 were rated as healthy. Suit and Knorr (10) reported finding the citrus

nematode in 12 of 115 apparently healthy groves examined. The complete distribution of the citrus nematode in Florida citrus groves is not known because no comprehensive survey has been made for this purpose. Citrus nematodes are carried to new areas on infested nursery plants.

The sting nematode, *Belonolaimus gracilis* Steiner 1942, was reported as causing possible damage to citrus in Florida by V. G. Perry and J. R. Christie in 1953 (unpublished data). Later, Suit and DuCharme (9) showed that it was not the cause of spreading decline; however, the parasitism of the sting nematode to citrus was demonstrated in 1954 (4). In our investigations relative to spreading decline, the sting nematode was found in 34 groves; 16 of these groves were affected by spreading decline, 14 had some other type of decline, and 4 were apparently healthy. A few groves have been found where a non-thrifty condition prevailed and the sting nematode was the only plant parasitic nematode present. Although the sting nematode feeds on citrus roots, the extent of damage and economic importance to citrus has not been completely evaluated. The observations made thus far on the relationship of the sting nematode to citrus indicate that this parasite should be considered as one of the important nematodes attacking citrus.

The meadow or root-lesion nematode, *Pratylenchus pratensis* (de Man) Filipjev 1934, has been reported associated with citrus roots in Brazil (5), California (11), and Florida (4 and 9). This nematode, is found in apparently healthy as well as diseased groves, Table 1. In our investigations, mature adults and larval stages of meadow nematodes have been dissected from cavities inside citrus feeder roots. They are also present in the soil about the rootlets. Meadow nematodes are easily extracted from infested citrus rootlets by incubating the washed rootlets for several days in closed pint jars. Since the meadow nematode seems to feed on and complete its life cycle within citrus-root tissues, we consider it to be a true endoparasite of citrus. Although the meadow nematode parasitizes citrus roots, no specific decline condition in a grove has been attributed to this parasite alone.

One of the lance nematodes, *Hoplolaimus coronatus* (Cobb) 1923, was reported in association with citrus roots in Florida in 1953 (9). This nematode seems to be common in Florida citrus groves, having been found in 56 of 255 groves examined, Table 1. It was not associated with a specific type of decline and was also present in apparently healthy groves, Table 1. Since *H. coronatus* is frequently found in groves, experiments were made to infest citrus roots with *H. coronatus*. Under the conditions of the experiments, *H. coronatus* survived but did not reproduce well, if at all, since only a few (adults) were recovered after one year from two of six inoculated sour orange seedlings. Occasionally a few specimens of *H. coronatus* were obtained from washed citrus root samples stored for several days in closed pint jars. Present evidence indicates that *H. coronatus* will feed on citrus and enter cavities in rootlets but is probably not of great importance. Its prevalence in groves warrants further study to determine its exact relationship to citrus and possible decline conditions.

Aphelenchus avenae Bastian 1865 was reported in association with citrus roots collected in Rhodesia (6), and from Florida in 1953 (9). This nematode commonly occurs in Florida citrus groves having been found in 109 of 255 groves sampled, Table 1. Although present in 68

groves with centers of spreading decline, it is not the cause of this disease. *A. avenae* probably occurs in association with disintegrating citrus roots only in a secondary capacity, feeding on fungi, bacteria, and decaying root tissues. This nematode is easily cultured in the laboratory on fungus cultures growing in petri dishes. When washed citrus roots are incubated for a month in closed pint jars, the population of *A. avenae* gradually increases while endoparasitic forms like *Radopholus similis* and *Pratylenchus pratensis* gradually decrease in numbers and disappear after two weeks. *A. avenae* is not considered to be of importance to citrus in Florida and there is no indication that it might be the cause of a citrus decline.

Seven other kinds of plant-parasitic nematodes have also been found associated with citrus roots in Florida (4 and 9). *Criconemoides citri* Steiner 1942 was found for the first time feeding on citrus roots in Florida by Steiner in 1942 (8). In our studies it was found in 39 out of 255 groves examined, Table 1. *Xiphinema americanum* Cobb 1913, was found for the first time in association with citrus roots in Texas by W. H. Reynolds (unpublished data). To date we have found this nematode in 19 of 255 groves examined, Table 1. Eleven of the 19 groves where it was found were classed as healthy, Table 1. *Hemicycliophora parvana* Tarjan 1952, *Trichodorus* sp. Cobb 1913, *Rotylenchus* sp. Filipjev 1934, *Hexatylus* sp. Goodey 1926, and *Aphelenchoides* sp. Fischer 1894, have been found occasionally in association with citrus roots in Florida, Table 1. None of these nematodes seems to be important to citrus and some of them are only rarely found.

The economic importance of *R. similis* has been adequately discussed elsewhere (4 and 9). *T. semi-penetrans*, the citrus nematode, is able to cause a definite but not well defined grove decline although its presence in a grove does not always mean that the grove is in a state of decline. The kind of injury and extent of damage to citrus caused by the other nematodes has not yet been demonstrated.

Of the plant-parasitic nematodes identified in association with citrus in Florida, *Radopholus similis*, *Tylenchulus semi-penetrans*, *Belonolaimus gracilis*, and *Pratylenchus pratensis* are true parasites of citrus. *Hoplolaimus coronatus* seems to feed on citrus but is not able to complete its life cycle with only citrus roots as the available food supply. *Aphelenchus avenae* seems to be present in and around disintegrating citrus roots as a saprophytic scavenger. The remaining nematodes are not known to be citrus parasites. Some of them probably do little or no damage to citrus, whereas others could be potentially important parasites capable of causing decline under certain conditions.

Tylenchulus semi-penetrans causes damage to citrus only. However, *Radopholus similis*, *Belonolaimus gracilis* and *Pratylenchus pratensis* are economically important parasites on other crops as well. Not much is known about the host range of the remainder of the species except that they have been found in association with the roots of citrus and other plants.

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NON-CITRUS PLANTS IN RELATION TO SPREADING DECLINE

R. F. Suit, E. P. DuCharme and T. L. Brooks *

Spreading decline of citrus in Florida is caused by the burrowing nematode *Radopholus similis* (Cobb) Thorne (3). Infestation of non-citrus plants by this nematode not only constitutes a threat to such plants, but also establishes a reservoir from which the nematode could possibly spread to nearby citrus groves. Knowledge of the susceptibility of non-citrus plants to the burrowing nematode is thus essential if the source of infestations, the rate of spread, and the distribution of spreading decline is to be properly understood. In addition, the effectiveness of any control measures applied to infested citrus groves would be influenced by the presence of other susceptible plants.

The burrowing nematode is known to parasitize the roots of 22 kinds of plants in various parts of the world (1). In Florida, it has been found on 26 species. Of these, citrus (3), avocado (2), and 13 other species (1) have been established as hosts and eight species (1) as possible hosts. Four of the latter 21 species are weeds or wild plants and the remainder are cultivated. Although the search for other hosts of the burrowing nematode in Florida is still in progress, some aspects of the relationship of non-citrus host plants to the spreading decline problem have been clarified.

Despite the fact that *R. similis* causes a decline of citrus trees, this nematode can parasitize many of the non-citrus hosts without producing visible symptoms in above-ground parts. Root lesions can be found in most cases if the roots are thoroughly examined under a microscope, but these would ordinarily go unnoticed. Nevertheless, the nematode, being endoparasitic, will be carried in the root system of an infested plant that is moved from one location to another. Consequently, these symptomless carriers pose a threat to the citrus industry. The lack of visible symptoms of infestation in many host plants is misleading, at least from the citrus side of the picture, since most people would consider the plants to be healthy.

In observing the area of spreading decline in a grove, it is evident when the source of infestation is from an adjacent grove, when from resets of infested citrus nursery stock, and when from the ornamental plantings in the lawn of a home adjacent to the grove. In other instances, the source of the infestation is not so easily found. It is known that many years ago certain areas were planted with bananas and pineapples. These plantings were not profitable and gradually died out. Some years later, citrus was planted. Subsequently, spreading decline appeared in some of these groves. The burrowing nematode could have been introduced by infested banana or pineapple plants and persisted on weed

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hosts until citrus was planted. In most instances, it is impossible to identify sites where cabins or homes were built in years gone by and what kinds of plants were grown around them. Evidence of a homesite may have disappeared, but weeds or ornamentals could maintain an infestation of *R. similis*. Thus, apparently virgin land may not be free of infestation.

Once an infestation of the burrowing nematode has become established in a grove, its rate of spread is about 50 feet per year. Any weed or cover crop host plants present in a grove could conceivably increase the population of *R. similis* and its rate of spread. Under such conditions, the area of infestation would be expected to increase at a more rapid rate than in absence of such susceptible plants. The burrowing nematode is able to go from one grove to another across non-planted strips of land, highways, or other areas. The usual distance between groves is short enough so that root contact between trees is possible. It would require a distance of over 125 feet before there probably would not be citrus root contact between groves. In this kind of situation, weeds and cultivated plants might also serve to spread the infestation and thus bridge the gap from one grove to another.

There are a number of ways in which the burrowing nematode has been or could be distributed throughout the State. As previously mentioned, the most obvious is the use of infested citrus nursery stock. A second way is through the distribution of infested ornamental plants. If ornamental plants were infested when purchased and shipped to other parts of the State, the burrowing nematode would be carried to new localities. This dissemination would not be noticed at the time, because many of the ornamental hosts do not show obvious symptoms indicative of infestation. Transportation of infested plants (ornamentals) from one friend's home to another's would, in a similar way, provide a means of spreading the nematodes. Still another means of spread is through importation of ornamental plants from foreign countries. If any of these were infested, they would introduce *R. similis* into nurseries where the plants were consigned or to home sites where they were planted. This is known to have occurred with Philodendron imported from Brazil. A recent shipment of Strelitzia plants from Hawaii was inspected at Tampa by the State Plant Board. This agency found a portion of this shipment to be infested with the burrowing nematode. The infested plants were destroyed.

By January 1954, research on spreading decline at the Citrus Experiment Station was sufficiently advanced to indicate the necessity of a survey on the extent of the disease on citrus in Florida. The State Plant Board was called upon to conduct the survey in the groves. Later, when proof was obtained that some citrus nursery stock and a number of ornamental plants were infested, the survey was extended to include all nurseries as well as groves. In considering the now-known host plants of the burrowing nematode in Florida and those that might be hosts, it is doubtful that the full extent of the burrowing nematode distribution in the State can be determined. It is anticipated that nursery inspection practices now being considered by the State Plant Board will be of much value in preventing new nematode infestations in the future.

In attempting to control spreading decline in citrus, the effectiveness of procedures such as the pull and treat method, the use of chemical

barriers, or fallow after pulling the trees will be influenced by the presence of non-citrus host plants. When a portion of a grove is pulled and treated, a sufficient number of apparently healthy trees to circumscribe the infested area—as well as the trees actually showing decline—are removed and that portion of the grove is treated with a soil fumigant. If a non-cultivated field or woods or a homesite is adjacent to this area, infested non-citrus plants could be present which would then serve as a source of reinfestation. The planting of ornamentals in a homesite adjacent to a treated area—or indeed adjacent to healthy groves—should be restricted to species not susceptible to the burrowing nematode. Where a barrier is being used to prevent the spread of *R. similis* in a grove, the growth of susceptible annual host plants in the barrier zone would enable the nematode to cross the barrier, even though citrus roots were not present. Such barriers should therefore be cultivated at least once a month to keep down the growth of susceptible plants. It is not known how long the land should be fallowed to control the burrowing nematode. The success of fallowing will depend on the absence of host plants on which the nematode can survive.

If the burrowing nematode were confined to citrus, there would be hope of developing a program that will control spreading decline. However, in view of the number of non-citrus host plants reported in Florida and the additional ones being found as the survey progresses, the problem becomes extremely complex. It appears that the only real solution, as far as citrus is concerned, is finding a highly resistant or immune rootstock.

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CONTRIBUTED PAPERS

BRONZING AND YIELD OF PEPPERS AS INFLUENCED BY VARYING LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZATION

C. T. Ozaki * and M. G. Hamilton **

The production of sweet peppers comprises an important part of the vegetable industry of Florida. During the 1953-54 season, over 13,000 acres [1] were planted to this crop with a large part being located on the sandy soils of the lower east coast. Fertilization practices vary a great deal in this area: the ranges of N, P_2O_5, and K_2O commonly used being 150-250, 300-550, and 100-150 pounds per acre respectively. Because of these wide variations in practices and the lack of experimental data, studies on the nutritional requirements of peppers were initiated.

EXPERIMENTAL

During the 1953-54 season, a fertility experiment was conducted at the Plantation Field Laboratory, Ft. Lauderdale, Florida, to study the effects of three levels of nitrogen, phosphorus, and potassium on the yield and quality of sweet peppers. The plots were located on Davie fine sand which had a pH of 5.0, an average moisture equivalent of 7.0, and levels of calcium and magnesium soluble in 0.5 N acetic acid of 620 and 190 pounds per acre respectively. Dolomite was applied to the entire experimental area at the rate of approximately 1,500 pounds per acre three weeks before seeding. The N, P_2O_5, and K_2O were applied at rates of 100, 200 and 300 pounds per acre in a 3x3x3 factorial experiment. The 27 treatments were arranged in a randomized block design with two replications. One-half of the phosphorus was applied at seeding and one-half at the first sidedress. Beginning at seeding, one-fifth of the nitrogen and potassium was applied in each of five applications at monthly intervals. Ammonium nitrate, superphosphate, and sulfate of potash were used as sources for the nitrogen, phosphorus, and potassium, respectively. A complete minor element mixture, containing copper sulfate, manganese sulfate, zinc sulfate, borax, and ferrous sulfate, was added to all plots. In addition, magnesium sulfate was included in the fertilizer mixture.

RESULTS AND DISCUSSION

All treatments resulted in a very heavy fruit set. A "bronzing" condition on the leaves was first observed on scattered plants shortly after the first harvest and was noticed to develop very rapidly thereafter. In

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the initial stages this bronzing appeared as an interveinal chlorosis on the immature leaves. In later stages the chlorotic areas assumed a definite bronzed color. Necrosis followed as the bronzing became more severe. Later the leaves dropped. This resulted in plants characterized by barren young stems protruding beyond dense foliage. Bronzing was not systematic, since the young leaves on one side of the plant often appeared normal while other young foliage on the same plant displayed severe bronzing. It appeared in the field that bronzing was less severe on that side of the plant adjacent to the center of the double row beds. Since the last two sidedress applications of fertilizer were applied in the center of the beds, it is possible that the nutritional requirements necessary for the prevention of bronzing was first met on that side of the plant receiving the fertilizer.

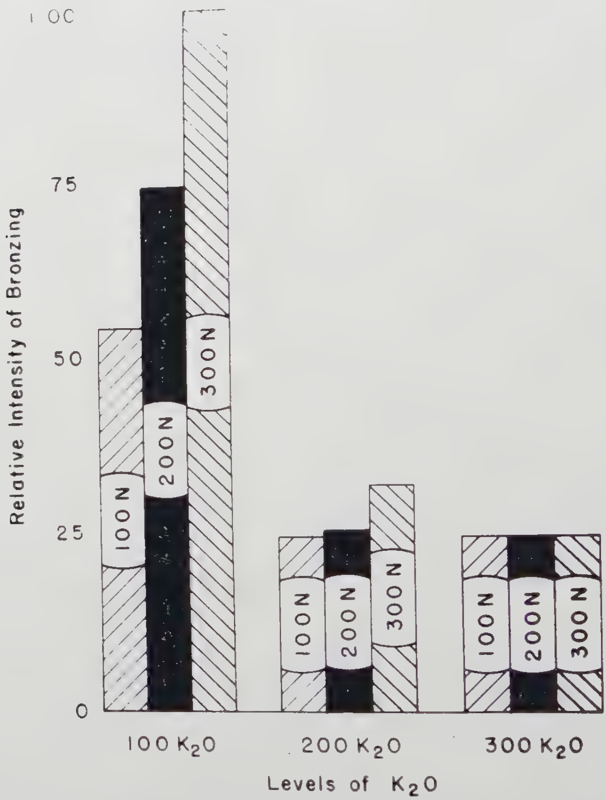

Figure 1.—The relative intensity of bronzing in pepper leaves as affected by levels of applied nitrogen and potassium.

Results from chemical analyses of leaf samples (Table 1) indicated that young bronzed tissue had a lower potassium content than more mature leaves from the same plant with little or no bronzing present. Field observations showed that bronzing was correlated with low levels of applied potassium. Each 100-pound increase in nitrogen resulted in in-

creased bronzing; whereas, each increase in potassium level decreased bronzing (Figure 1). These nitrogen and potassium responses were found to be related. At the 100 and 200 pound nitrogen levels, increasing the potassium from the 100 to the 200 pound level reduced bronzing. Although bronzing was rather severe at the lowest rate of potassium under all nitrogen applications, each 100-pound increase in nitrogen level resulted in a significant increase in bronzing. At the 200-pound potassium level, it was necessary to increase the nitrogen application to the 300-pound level before a significant increase in bronzing was observed. Nitrogen had no indicated effect on bronzing at the 300-pound potassium level. All plants receiving this treatment were nearly completely devoid of this condition. In this study the levels of phosphorus (100, 200, 300 pounds P_2O_5) had no significant effect on bronzing.

TABLE 1.—THE POTASSIUM, CALCIUM, MAGNESIUM, AND PHOSPHORUS CONTENT OF PEPPER LEAVES.

Condition of Leaves	K—%	Ca—%	Mg—%	P—%
1. Severely bronzed (immature leaves)	0.32	1.87	2.00	0.66
2. Early stages of bronzing	0.88	1.57	1.75	0.59
3. Old mature leaves (no bronzing)	1.24	2 45	1.75	0.63

As shown by Figure 2, levels of applied potassium and nitrogen had significant influences on the potassium content of immature pepper leaves sampled approximately two weeks after the last sidedress. The potassium content of the leaves was significantly increased by each 100-pound increase in applied K_2O, with values of 1.50, 2.73, and 3.84 percent reported for the 100-, 200-, and 300-pound K_2O applications, respectively. As indicated earlier, no bronzing was observed in the leaves of plants treated with the 300-pound K_2O level. Increasing the nitrogen from the 100- to the 200-pound level resulted in significantly lower concentration of potassium, but phosphorus had no effects. The influence of nitrogen on the potassium content could not be related to increased size of plants, because size was affected only by varying the level of applied potassium; increasing the latter to the 200-pound level resulted in significant increases in width and height of plants.

Both nitrogen and potassium produced significant influences on the color of the leaves, but phosphorus had no visible effect. Each 100-pound increase in applied nitrogen resulted in a darker green color. In contrast, increasing the potassium from the 200- to the 300-pound level significantly decreased the intensity of green color. This response to potassium was dependent upon the nitrogen level involved. Fruit color appeared to vary directly with the color of the foliage.

The potassium content of the fruit was increased by each increment of K_2O added, whereas nitrogen and phosphorus had no significant effect.

Significant increases in both weight and numbers of U. S. 1 and total marketable fruit were obtained by increasing either potassium or nitrogen to the second level. Significant increases in the numbers and weight of

U. S. Fancy grade fruit were obtained as the potassium was increased from the 100- to the 200-pound K_2O level. Data in Table 2 are for total weights of marketable fruit only. No responses to nitrogen were obtained at the low potash level; however, at the high potash level each increment of nitrogen resulted in significant yield increases. With the two lower nitrogen levels, significant increases in yield were obtained only to the second level of potassium. Each increase in potassium significantly increased yield at the high nitrogen level.

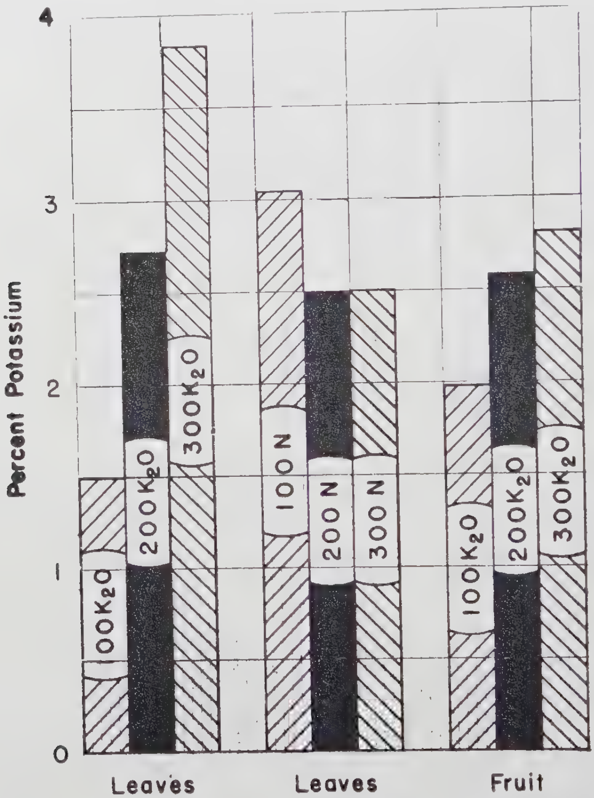

Figure 2.—The postassium content of leaves and fruits of pepper plants as affected by levels of applied nitrogen and potassium.

SUMMARY

A bronzing condition in young pepper leaves was inversely correlated with potassium content of the tissue. Such levels were changed either by rate of potassium applied or by the nitrogen-potassium ratio of the fertilizer. Levels of applied phosphorus had no influence on bronzing.

The potassium content of the fruit was significantly influenced by the rates of K_2O applied.

Yields of total marketable fruit were significantly affected by level of applied nitrogen and potassium. The yield response to nitrogen and

potassium were found to be interrelated. Phosphorus level did not significantly influence yield.

TABLE 2.—Total Weight of Marketable Pepper Fruit per Plot as Influenced by Levels of Nitrogen and Potassium.*

	100 N	200 N	300 N	Average
100 K_2O	121.2	133.7	117.2	124.1
200 K_2O	166.8	180.5	184.1	177.1
300 K_2O	161.8	191.1	215.4	189.4
Average	150.1	168.4	172.2	

L.S.D. (.05) between nitrogen and potassium level 13.65
(.01) between nitrogen and potassium level 18.45
(.05) between nitrogen x potassium level 23.71

* Area of individual plots = 0.0066 acres. Weight expressed in pounds.

Size of plants was affected by levels of potassium applied.

Both nitrogen and potassium produced significant influences on the color of leaves, but phosphorus had no visible effect.

PROGRESS IN THE HARVESTING AND PROCESSING OF RAMIE AND KENAF

R. V. ALLISON and JOHN W. RANDOLPH *

The many materials on display here at the front of the room—yarns, threads, ropes and fabrics of a wide variety of textures that have been made from ramie and kenaf are suggestive of the fact that neither fiber represents a particularly thoretical situation even though a certain amount of work remains to be done on both before they can be regarded as entirely practical for the small grower under Florida conditions. As a matter of fact, it is the rather unusual progress that has been made during the past two or three years with one of the principal problems connected with their practical handling that we wish particularly to discuss this evening. Reference is to the development of equipment for the harvesting and ribboning of these plants in the field.

In entering upon this discussion we will take for granted that most of you know in a general way that both ramie and kenaf are bast fibers; that is, their fibers occur just beneath the bark of the plant and extend the full length of the stem in this position. In other words, these fibers are the plants' plumbing or conducting tissues. The contrast between these two fibers is readily evident from the material exhibited here this evening, those made from ramie being characterized by the linen-like yarns and fabrics or the grey, tough-looking canvases or beltings and the kenaf by the jute-like yarns and fabrics that appear very much like burlap. In fact kenaf is a very satisfactory substitute for jute and in some uses, such as for carpet backing, is frequently regarded as superior to it.

Doubtless most of you also know that ramie is a perennial which, for commercial purposes, can be propagated only by vegetative means. In this respect it is very similar to sugar cane in that it need not be planted but once in several years. Unlike sugar cane, however, ramie can be harvested about every two months thru the summer season, the period, as to the exact number of days varying, seemingly, with the season. In South Florida three cuttings are expected each summer. A normal growth of ramie and kenaf at harvest time is shown in Figs. 1 and 2, respectively.

The superior qualities of ramie fiber from many standpoints—length, strength, absorptivity and sheen—when properly processed, have been known for many centuries. In fact, it has long been regarded as the most outstanding of all plant fibers in many respects. Nevertheless, its practical culture under modern conditions has been balked, or at least made economically impractical, until recent times, through the lack of mechanical means for its recovery from the peripheral tissues of the plant stem in which it is embedded, a process that is known as decorticating or ribboning in bast-fibered plants of this nature.

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Inasmuch as the removal of the central part of the stem of these plants in the recovery of the fiber as a ribbon made up of the peripheral tissues is commonly accomplished by some form of beating or scraping (raspidor) action, it is believed that the presentation of a series of diagrammatic sketches showing some of the machines that have been tested, are being

Figure 1. Mature stand of ramie ready for harvest. Note that the growth has extended from original lines of planting (in rows 3 feet apart and 2 feet in row) to a solid stand. This fact makes it necessary to handle the harvest as for a broadcast crop.

used, or under development might be the best means of getting an overall view of this field of effort. These follow as a series of six figures or sketches, two being used for the Krupp-Corona type to show the general layout and the detail as to operation since this is the large, central unit that has been almost exclusively used for the recovery of ramie fiber in Florida up to the present time. In this series particular attention is therefore called to the Mohegan Krupp-Corona, Nos. 4-A and 4-B, No. 5, The Cary Harvester-ribboner which is currently creating much interest and No. 6, the small, hand-fed Baproma which is proving so useful in making experimental harvests for total fiber yields. A number of others could be mentioned, including the Alfab-Marti, the Bobkowicz sliver ribboner, the Padilla descintadora, the Patterson, St. John's Nanjer, and the Erb. However, as yet they have not been developed sufficiently, all being hand-fed, to appear useful under Florida conditions.

Figure 2. Normal growth and stand of kenaf at maturity for fiber yield. Harvesting is shown thru the use of a modified hemp binder such as was used for the 1951 and 1952 crops which were largely put through a Krupp-Corona unit with heavy loss of fiber.

While the heavy Corona and other essentially raspidor units such as the Diamond Huller normally produce a somewhat cleaner ribbon, fiber losses are involved that are sometimes quite serious especially in comparison to some of the simpler procedures. Nevertheless, the end product is essentially the same since the ribbons in either instance subsequently must be put through a degumming or "laundering" process for the removal of the matrix material in which the fibers are imbedded. This will be discussed in greater detail later.

Although ramie plantings were made at the Everglades Experiment Station, Belle Glade, as early as 1929 to test its growth on the remarkably productive soils of this area and these studies have been continued and expanded through the years, it was not until Newport Industries, Inc., became interested in this field of production on a commercial basis in 1943-44 that the project really began to take form as a potential industry for this section.

Without going into detail regarding culture and yield, it is suffice to say that the growth of the crop has been eminently successful when given good conditions of culture and adequate attention is given to water table control in the soil. In other words, ramie will not tolerate flooding or even a too high water table for a comparatively short period. However, such extra cost as may be required for special attention in this respect is substantially compensated for by the comparative freedom of the plant from diseases and insect pests.

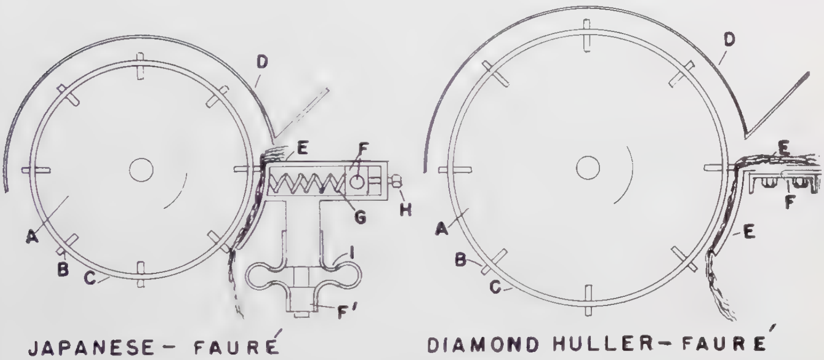

Figure 3. The Japanese Faure (left) and a modification, the Diamond Huller (right) have been used thru the years for fiber recovery on a limited field scale and more recently for control studies in the harvesting operation. Both units are hand-fed with 2-3 canes at a time, top first and after withdrawing repeating the treatment on the bottoms of the stems.

A—Disc hub fitted to drive shaft. B—Beater bars recessed in hub. C—Holding ring. D—Cover plate. E—Breast plate on Diamond Huller is in fixed attachment to main frame. E—Breast plate on Japanese unit is spring mounted (Note G and I make connection to F and F') in order to "give-way" when feeding canes and to obtain fullest degree of fiber cleaning as the fibers are removed from the processing actions. H—Clearance adjusting screw.

As already has been mentioned, the particular purpose of the present discussion is largely to emphasize the important progress that has been made during the past 2 or 3 years in the development of a field harvester-ribboner for these crops that represents a sufficiently limited investment to permit the smaller grower to engage in their production.

Thus, since the beginning of the ramie project at the commercial level, practically all processing has been done at a central plant involving heavy equipment that has centered around the Krupp-Corona decorticator sketched in Figs. 4-A and 4-B. This is a large, raspidor type that originally was developed and found most useful for leaf (hard) fibered plants such as abaca (manila hemp), henequen, sisal, sansevieria, etc. Inasmuch as such an installation, with all its appurtenances, when set up and ready to operate costs a quarter million dollars or more and requires at least 2,500 acres of ramie to keep is reasonably busy through the 50-day harvest cycles of the summer months, it is readily seen why the small grower has remained on the sidelines during the early stages of development.

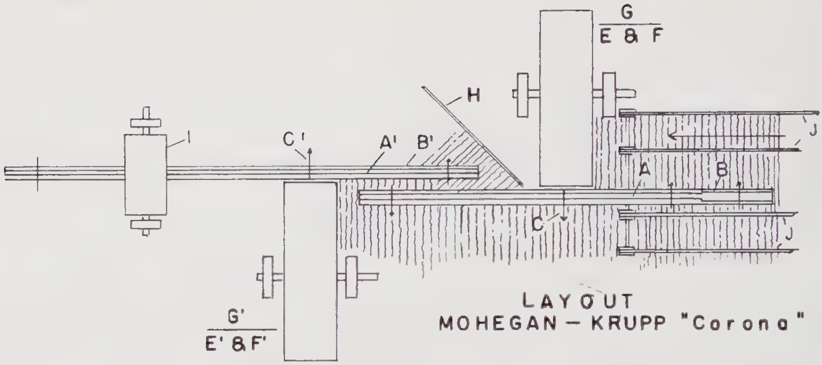

Figure 4-A. General layout of Krupp-Corona unit from the entering mat of canes on the right to the rolls for dewatering the washed and cleaned fiber on the left.

A and B—Rope grip conveyor. C—Master sheave in line with decorticator. H—Fiber lifters to permit feeding into rope conveyor. I—Dewatering rolls. (See sectional view on second sheet.)

$\frac{G}{E \& F}$ Cover 'G' over Blades 'E' mounted on fly wheel 'F'.

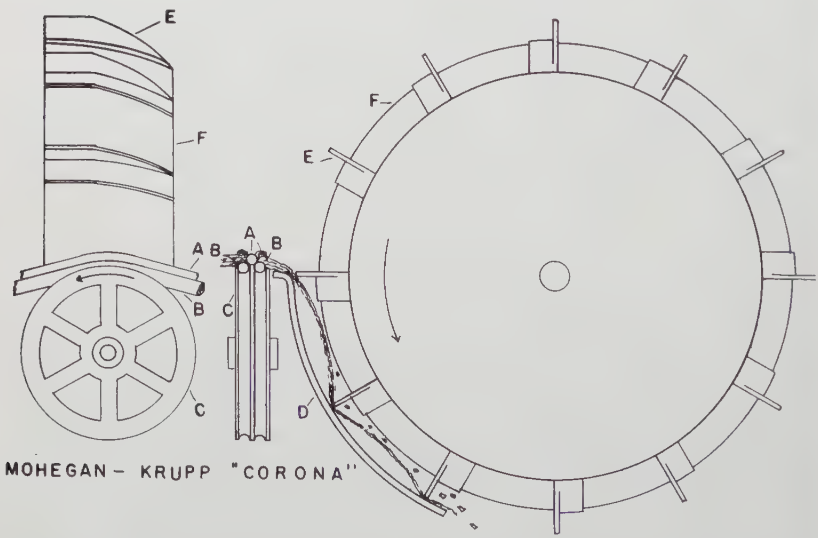

Figure 4-B. Detailed view of "first rotor" in Krupp-Corona unit showing the holding of the plants by the rope grip as the tops (or butts on the second wheel) pass between the breast plate and fast moving blades or beaters of the rotor.

A and B—Rope grip conveyor. C—Master sheave in line with decorticator. D—Ground breast plate. E—Curved beater blade. F—Heavy, side-crowned rotor. Note: Water is heavily sprayed on beater drum at point of greatest action.

However, the rapidly mounting interest of the small farmer in ramie culture in Florida has caused an ever-increasing amount of effort to be placed in the development of a satisfactory field machine. Most rapid progress in this connection has been made during recent years by the Cary Iron Works of Opelousas, La. Each season during this period this company has brought improved models to Florida and carried on a rigorous succession of tests and changes that have resulted in a steady improvement in the performance of the unit. The present form of this harvester-ribboner as it is to operate in Florida this spring is well shown in Figure 9,

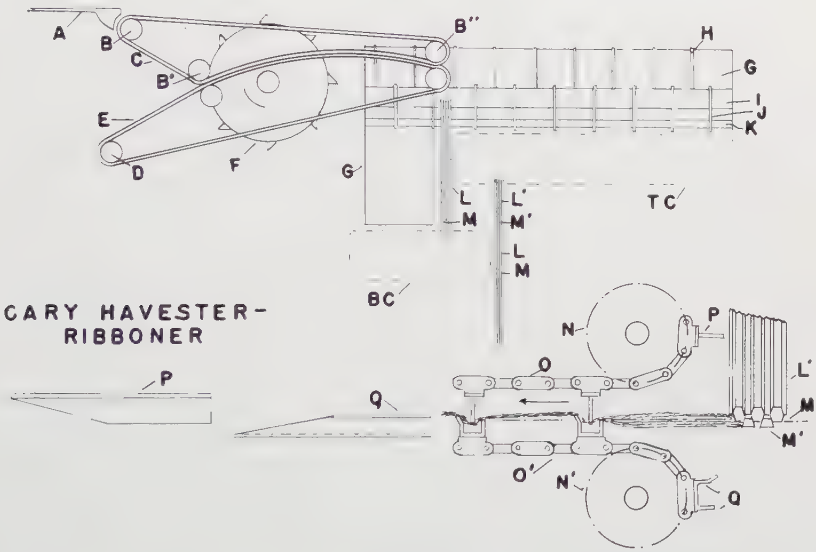

Figure 5. Cary harvester-ribboner, in the form of the third model, which harvests and ribbons ramie or kenaf in a single operation. Depending upon conditions which have not as yet been fully integrated and studied this unit recovers from 55 to 75 percent of the fiber in the field with all the advantages of a field operation that are hereinafter discussed. (See also Figure 9.)

A—Swath divider. B—Sheaves for 'V' belt. C—'V' belt. D—Sprockets. E—Special chain with spike fingers. F—Rotary cutter. G—Table surface. H—Cross-feeding belts. I—Crushing roller and drive for belt J. K—Roller. L—'V' belt sheaves. M—'V' belt grips. N—Sprockets. O—Roller chain in two strands that support top cleaner bar P which intermeshes with double cleaner bar Q. Note: Cleaner bars are tapered so that their cleaning action on the canes is more or less gradual.

where it is working on a comparatively young stand of kenaf, the substitute for jute that has aroused considerable interest in the U. S. and Cuba as well as other Caribbean areas during the past few years. In the photo it is to be noted that two men are required to remove the ribbons and twist them into stricks for placing on the platform when operating in such a dense growth of plants as is there shown. Inasmuch as kenaf and ramie are both bast-fibered plants, it operates equally well or even better in ramie since the height of the plants and density of stand in the latter usually are substantially less than kenaf. Particularly to be noted

in the photo is the uniformity of the cut and good distribution of the trash that is left in the field, a factor of particular importance in the instance of such a perennial as ramie.

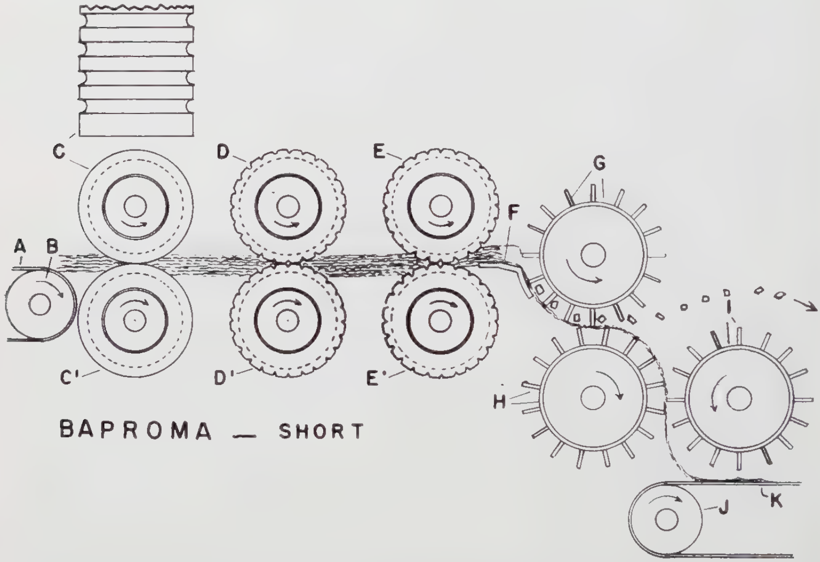

Figure 6. The Baproma, a hand-fed ribboner that has been found particularly useful in experimental work since all fibers are recovered in the ribbons from the stems that are fed thru it. This unit is also shown as Nos. 2 and 3 in the group of Figure 10.

A—Feed belt. B—Pulley. C—Grooved, rubber feed rolls. D and E—Cross-grooved feed rolls. All feed rolls have soft rubber centers to avoid crushing of canes as much as possible. F—Double-angled breast plate. G, H and I—Bladed beater and cleaning cylinders. Note: Stem speed thru machine six feet per second for 5 to 10 canes depending on size. This unit handles all types of fiber canes equally well—ramie, kenaf, jute, sida, etc., delivering a complete ribbon without loss of fiber.

In view of the present availability of such a field machine for the simultaneous harvesting and ribboning of ramie, the interest of local growers in it is readily understandable. In other words, this manner of handling will not only (a) by-pass the heavy first investment in a central plant but also (b) avoid the great cost of hauling thousands of tons of gross plant material thereto for the extraction of an unusually small percentage of a desirable component, at least small as such plant handling goes, with (c) avoidance of heavy damage to fields, roads and mill-site under average rainy season conditions when the harvests must be made. There is the further advantage, too, of (d) leaving this enormous quantity of plant waste in the field where it properly belongs not only to serve as a supplement to fertilizer residues but also as a source of fresh energy material to keep the micro-flora of the soil strong and active. Strange as it may seem this is highly desirable even in the organic soils characterized by our Everglades peats. A final point in favor of the field operation in contrast to the heavy massive action of the central plant

is (e) the substantially higher fiber recovery that is accomplished thereby. a fact that is bound to add to the overall economy of production in a very substantial way.

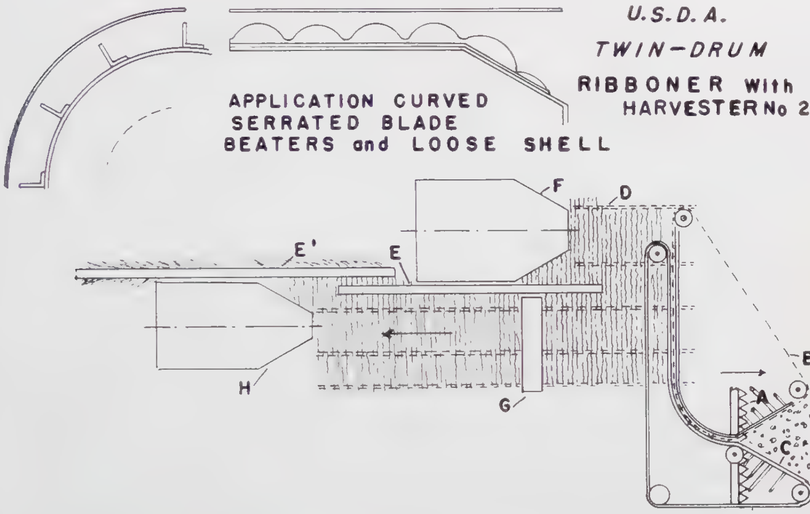

Figure 7. The U.S.D.A. twin-drum, harvester-ribboner represents essentially the mounting of a harvesting device to cut and deliver the canes to the feed table of what was originally developed as a twin-drum brush for aligning and cleaning Corona ribbons by way of preparing them for stapling and degumming. To date no quantitative field studies have been made on this unit.

A—Standard mowing machine cutter bar mounted on master frame. B—Gathering chain. C—Gathering rope. D—Platform feeding chains. E—Grip feeding chains. F—Tapered end drum fitted with curved, serrated blades. Unit covered on top by a loose shell. G—Small-diameter butt-crushing rolls. H—tapered end drum as F.

Before leaving the mechanical handling of the crop in the field, mention also should be made of the very considerable progress that has been made in the development of a small. hand-fed type of ribboner for operation under field conditions. Here again, as among the units that have been studied at the Everglades Station, a maximum of perfection seems to have been found in a unit developed by Mr. Charles R. Short and his associates at Clermont. This machine is now known as the Baproma and currently is being produced in Austria, for use in those parts of the world where bast fibered plants are grown and where the low price of labor will permit the amount of manual handling that is required in the operation of a unit of this nature. This small unit is shown in two views, 2 and 3, in Figure 10 where other conditions that concern the culture of ramie in South Florida are shown and described as a brief sequence.

With a stem speed through the machine of 6 to 8 feet per second a group of 10 or 12 ramie stems of average size, a smaller number of larger kenaf stalks, of course, will clear in about one second following engagement by the feed rolls and the ribbons, fairly well butted, will land on the double cross bar at the rear of the unit with the bottoms on the side

farthest from the machine since they are the last released and are thrown to that position by the fast moving belt on which they momentarily fall.

One of the most interesting and practical features of this small unit, aside from its speed, is the fact that it recovers all of the fiber from the plant stems that are fed thru it and delivers it in ribbon form on the cross-bar. This is of particular interest to us here at the Experiment Station for the excellent use it serves in experimental harvests since it does recover all of the fiber. This is in contrast to most of the units heretofore used for this purpose which, being of the raspidor type, produce fiber losses varying from 10 percent to as high as 30 to 40 percent depending, seemingly, on the condition of the stems from several standpoints at the time of ribboning.

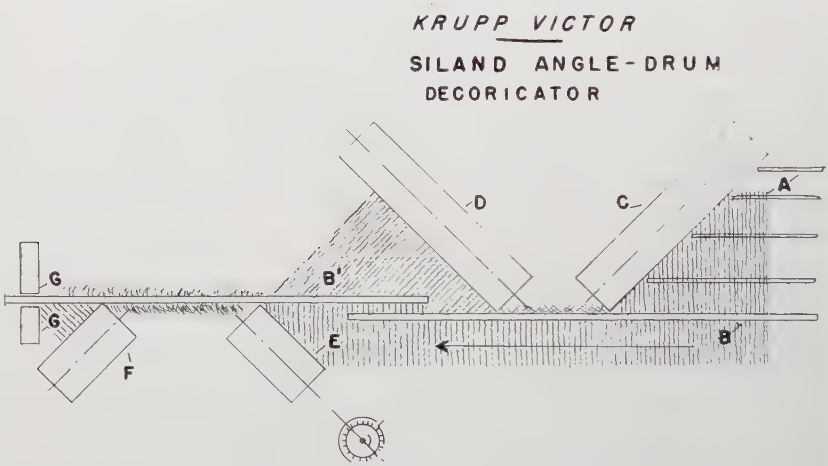

Figure 8. The Siland, an American-made angle-drum ribboner or decorticator was modeled quite closely after the Krupp Victor which was probably the first heavy unit designed specifically for bast-fibered crops, the Corona having been produced for hard or leaf fibers such as abaca, henequen, sisal, etc. This unit has produced good clean (unwashed) ribbons with the usual losses developed by the raspidor types, especially in cleaning the bottoms of the stalks.

A—Feeding chains over a table. B—Grip conveyor with rubber pads on roller chains. C, D, E and F—Heavy, precision-built drums fitted with curved beaters which have uniform clearance from a ground-surface breast plate. Drums C and E have wide clearance which makes them ribboners. Drum D and F have close-fitting breast plates to obtain maximum cleaning action. G—Dewatering rolls.

A further point of interest in connection with this little unit is the possibility of at least partially mechanizing the feed since it is apparent from the above that it cannot possibly be kept occupied by manual feeding. If a satisfactory mechanical feeding is accomplished we would have still another unit that might prove of practical interest to some Florida growers. This, of course, would be satisfactory to all who are interested in or concerned with the production and processing of these crops since it is largely thru competitive effort that most rapid improvements are made in equipment of this nature.

A point of particular interest in connection with the processing of these plants that is receiving much thought at the present time is the matter of cleaning such ribbons as these field machines produce by way of preparing them for degumming. For our own part it is the belief that these ribbons should be regarded only as a definite step or stage in the harvesting process and the removal of bits of shive or wood and as much bark as possible, following drying, treated as a necessary and separate operation. Naturally, if properly mechanized, this can be accomplished at quite a small cost. Some form of washing of the green ribbons with or without a light concentration of detergent or passing thru a short period of natural heating which causes both ramie and kenaf ribbons to become quite soft and slimy logically suggests itself. Naturally careful control will be necessary to avoid injury to the fiber. Following such treatments and subsequent washing and drying the ribbons would be mechanically softened to remove the wood, bark, etc.

Figure 9. Cary harvester-ribboner working with a 75-day kenaf stand in an experimental planting on Everglades peat near Canal Point. Note the excellent condition in which the crop waste is left spread over the land and the undisturbed surface of the soil after the machine has passed over it. Both men shown at the right of the machine are busy removing the ribbons from the conveyor belt and twisting them into stricks for the platform at their right from which they are periodically unloaded.

In order to give a very general idea of the relations of these fibers to all of these processes including degumming, this last process which occurs just prior to the softening and carding operation will be touched on at least lightly. As already referred to, the degumming of these fibers whether by natural retting or by chemical means to break down and mobilize the matrix material is little more than a laundering process. Thru the years this largely has been accomplished for jute and kenaf by the natural retting of the whole stems. More recently, at least in the Western Hemisphere, the retting of kenaf ribbons has become a common

practice with only a limited amount of chemical retting on an experimental basis.

Figure 10. A brief sequence in ramie culture in the Everglades showing: (1) Varietal plots at the Everglades Experient Station; (2) Rear view of the hand-fed Baproma ribboner (quiet); (3) Rear view of the Baproma ribboner in operation with "ribbons" on the cross-bar; (4) Cary harvester-ribboner operating in ramie fields of Newport Industry, Inc., Canal Point, cut field in background; (5) Truck load of baled, field ribbons wrapped for export to Europe for special study; (6) Ramie stems partially ribboned and degummed showing the amount of fiber and its peripheral location.

In the instance of ramie, however, natural retting is not possible except with very special control of the organism that does the work. At least it has been reported as successfully retted in Europe thru the use of the proper organism. Consequently thru the years ramie has been consistently degummed by exposing the ribbons either in full length or after stapling at some predetermined length to fairly high temperatures and pressures (15 to 75 lbs.) in a solution of caustic soda varying from 5 to 10 percent thru a period of 3-5 hours.

By way of indicating current studies that are in progress in this field we are privileged by Mr. Charles R. Short of Clermont to state that practically complete degumming of either ramie or kenaf ribbons has been

accomplished in 3-5 minutes by an in-line procedure (handling the ribbons in full length) which passes the material between a series of fluted rolls (while held between 1/4-inch mesh belts) in such a way that they are worked by reciprocating action thru a period of a few minutes while immersed in a fairly weak chemical solution at 150-160° F. A solution that has been found quite satisfactory is 0.25% caustic soda and 0.25% detergent. While the high pressure and high concentration of chemical used in the system (kier) now in common use dissolves any and all bark (but not the fine particles of wood) that may remain on the ribbons, this will not occur in such an open system as has just been described. On this account any and all bark must be cleaned from the ribbons prior to degumming by this method that cannot be removed by the mechanical processing they will receive after washing and drying, that is, thru the softening, carding and combing operations. Particular mention is made of this point since it already has been stated that the cleaning of the ribbons in preparation for the degumming process might logically be regarded as a part of the harvesting operation and the field harvesters to leave a considerable proportion of the bark on the ribbons under most conditions of operation.

While the world market for jute is far below that which so stimulated the kenaf project in Florida in 1951 and 1952 there is no such situation extant for ramie when the essential qualities of the fiber are fully taken into account even in comparison to the best synthetics.

The possible uses for ramie between such broadly different products as have been shown during this discussion are, of course, very extensive in number particularly when it is recalled that ramie is several times as strong as any other vegetable fiber, that it can be recovered and processed in almost any length desired up to 10-12 inches (fibers 20 inches in length have been observed) and that it is exceedingly absorptive both as to dyes and moisture and will give up the latter readily thus making a "cool" fabric when used for wearing apparel. Further to the above ramie has been found to be approximately 60 percent stronger when wet which makes it ideal for use in fire hose, fish nets and marine cordage of all sorts. Again, a wide adaptability can be found for it through the fact that, when properly degummed, it resists mildew under the most strenuous conditions of climatic exposure even such as are commonly found in the tropics.

The characteristics of this fiber that have been briefly recited above and the fact that our Everglades soils have proven a "natural" for its growth by showing ready capability of producing an average acre yield of 1,500 to 1,800 pounds per year from three cuttings should provide good and sufficient cause for the current development of interest in the growing of this crop among small farmers, especially when viewed from the standpoint of the rapid improvement of mechanical means for harvesting that has developed during the past few years. Indeed, all Florida and all U. S. might well give thought to putting their collective shoulder to the wheel and assist in the development of this important industry if for no other reason than that of establishing a truly continental (U. S.) supply of a remarkably durable fiber which so readily will find an important place in the national economy whether our country be at peace or at war.

THE FUTURE OF SOFT FIBERS IN FLORIDA

HARLEY G. MORTON *

Calloway's Textile Dictionary defines soft fibers in this manner: "flexible, elongated, soft fibers extending through the inner bark of the main stem or stalk of certain dicotyledonous plants. These plants, as a rule, are annuals bearing fibers which may be obtained by the process of retting. Among the well known soft fibers are flax, hemp, jute and ramie."

The discussion in this paper will be concerned only with the soft fibers grown in Florida on a commercial scale, namely, ramie and kenaf. The history of the development and the use of soft fibers dates back many centuries to make a most interesting story. The historical phase of ramie has been related in the Proceedings of the Soil Science Society of Florida, Volume XI, 1951, and by the Progress Report prepared for the U. S. Department of Commerce, by the U. S. Department of Agriculture and the Florida Experiment Station in 1948. Therefore, I will only attempt to evaluate our present position as to the volume of production, markets and future growth of the soft fiber industry.

KENAF

The high degree of mechanization in the United States in the manufacturing, distribution and agricultural fields requires a constant and dependable flow of all types of raw materials consumed and the avoidance of extreme price fluctuations. Delays in the delivery of any one item may have serious repercussions in the production cycle, particularly where it interferes with the operation of costly equipment on planned schedules. Uncertain availability of burlap, unreliable deliveries and high prices in the post-war period, especially after the partitioning of India, caused serious disturbances in the domestic burlap trade and among burlap customers. Burlap requirements of the United States have been about 70 million yards per month with India supplying about 60 million of the total amount. By 1950, the production of burlap in India had declined sharply because prices on jute and jute products were being maintained by India mainly in an effort to increase food production. Furthermore, political differences between Pakistan and India were influencing the flow of jute from Pakistan to the mills of India. India then began allocating its curtailed supply of burlap to the world markets with the result that in January 1951, the amount available to the United States was 44 millions of yards. It appeared unlikely that the domestic share of India's production would exceed this amount for the remaining 10 months of the year.

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* Director, Textile Group, Office of Program and Requirements, Defense Production Administration, Washington, D. C. (Appointed Fiber Technologist, effective February 1, 1955, by the Florida Internal Improvement Board particularly for the industrial development of soft fibers, especially ramie and kenaf, in cooperation with the University of Florida with headquarters at the Everglades Experiment Station, Belle Glade.)

KENAF PROJECT

The many uncertainties in the burlap situation focused attention on this country's dependency on a source of supply from Calcutta, half way around the world. This was largely responsible for encouraging the kenaf project in Florida. Cuba and Mexico, which has been started in a small way in the Caribbean countries several years before.

Search for jute substitutes which could be developed economically also has been made in some areas of Africa, notably, the Union of South Africa, and in many countries of the Western Hemisphere including Argentina and Brazil. Such fibers as phorium, figue, and urena lobata have been tried with some success. Kenaf (Hibiscus cannabinus), under various names, has been grown in many areas of the world. In India where it is called meshta or mesta, large quantities are grown for substitution of or mixture with jute fibers in the manufacture of certain articles. It is difficult to distinguish the two fibers in the finished product.

It has been found that kenaf fiber can be grown to better advantage in the Western Hemisphere, but the processing of the fiber has presented problems. Water retting, the customary method in India, does not appear to be practical in the highly developed areas of the west. However, preparation of the fiber by decortication or the mechanical removal of the fiber sheath from the woody portion of the stems, now appears feasible.

A kenaf fiber and seed program certified by the Defense Production Administration in 1951 provided for the procurement through the Commodity Credit Corporation of 4 3/4 millions of pounds of fiber and 4 3/5 millions of pounds of seed. Shortage of seed and inadequate fiber extraction machinery caused the 1951 goal to fall considerably short of its objective. The program was continued in 1952 with a goal of 15 million pounds of fiber, one-third of which was to be produced in Florida. Every grower of kenaf lost money because machinery for the economical harvesting and decortication had not been developed. This situation still exists. However, the Cary harvester and ribboner, now being used to harvest ramie with a high degree of success, may also solve the problem of the mechanical harvesting of kenaf.

To develop the necessary experience in the mechanical harvesting and decortication of kenaf it has been suggested that the U. S. Postal Department make tests of cordage made from kenaf. If satisfactory, they could specify kenaf fiber in all their cordage requirements. This would develop a small industry and the know-how in dealing with these problems. It is within the realm of possibility that the Department of Defense will give support to the stockpiling of kenaf fiber along with sisal and abaca to supplement the shortage of jute in the event of full mobilization.

RAMIE

The use of ramie fiber by man began many centuries before the time of Christ. From its Oriental origin ramie was gradually distributed to other areas of the world where its uses were developed and broadened. It was grown experimentally in the southern sections of the United States since its introduction in 1855. Since 1943 it has been grown commercially in Florida.

There are many industrial uses for a high strength yarn such as ramie. Fire hose, both flat and V-belts, fish nets and cordage are examples. When it is spun into fine count yarns it can be woven into cloth that has much the same luster and sheen as fine linen. When blended with wool in the staple prior to spinning it cuts down the shrinkage, increases the strength of the cloth, and its crease resistance. Such fabrics would be in demand by the garment manufacturers.

The defense requirements of our country have played a leading role in the economy of our nation for the past several years. It is my opinion that the use of ramie as a defense item has great potentialities. An account of a change in the construction of one uniform cloth during the Korean War will serve to illustrate. The all-wool cloth weighing 18 ounces per square yard used by the Army for uniforms during this period was changed in construction. With the wool was blended 15 percent of nylon staple yarn. Since this increased the strength of the cloth more than 50 percent it was possible to reduce the weight of it to 16 ounces per square yard. Yet the end item furnished at least 50 percent more service and reduced the amount of wool consumed by 25 percent which saved many millions of dollars in our defense expenditures. Had ramie fiber been available in quantity I feel sure it could have accomplished a similar result.

TOTAL FIBER CONSUMPTION IN THE U. S. A. FOR THE YEARS 1945 TO 1954.*
Unit 500 Pound Bales.

Year	Cotton	Man-Made Fibers
1945	9,144,444	1,684,000
1946	9,832,814	1,814,000
1947	9,546,151	2,050,000
1948	9,095,142	2,394,000
1949	7,873,203	2,178,000
1950	9,649,675	2,806,000
1951	10,036,880	3,006,000
1952	9,180,101	2,796,000
1953	9,308,143	2,994,000

* Textile Organon Feb. 1954.

Ramie was tested by the Army-Navy Research and Development Board in 1951 for use in cartridge cloth in place of silk waste and noils. It was found to function equally well or better than the material being used. Purchase specifications have been written by the Ordnance Department and when sufficient fiber is available a large amount will be used. There are many other defense requirements that demand high strength yarn, now supplied by extra long staple cotton, which ramie would serve better and at lower cost. Defense items that could be made from ramie fiber include the following products: camouflage netting, duck, tropical uniforms, halyards, ammunition belts, mattress covers, jungle helmets, collapsible water buckets, narrow fabrics and webbing. These items consume many millions of pounds of yarn made from extra long staple cotton. The U. S. Department of Agriculture had a support price on extra long staple cotton of $1.04 per pound for the crop year of 1952-53 while degummed ramie sold for 70 cents per pound!

The production of ramie for the year of 1953 was approximately 3 million pounds, much of which was sold for export to Japan, France, Germany and Switzerland. In 1954 about the same amount will be produced and of this amount about one-half million pounds will be degummed and consumed in the U. S. A.

With an increase in population of approximately 2 percent each year and with an even greater percentage increase in the Gross National Product, why does the consumption of cotton remain static while that of man-made fibers increases over 75 percent during the past nine years? There may be many reasons, yet I believe that research, development and market promotion and an ample supply of fiber to meet the manufacturers' requirements are the principal reasons.

With this brief review of the civilian and military uses for ramie and kenaf we make the following recommendations to the State Department of Agriculture and to the University of Florida:

1. Initiate research in the development of new and improved fabrics by blending in the staple of ramie with cotton, rayon and wool.
2. Promote the use of ramie in many defense items requiring high strength yarn that will give long service under practically all conditions of climate.
3. Advocate the use of kenaf in the cordage industry by placing samples in the several departments of government.

We believe there is a market waiting for the producers and spinners of these fibers that will require many millions of pounds per year which would put into use thousands of acres of South Florida land that are now idle.

BUSINESS MEETING

The regular business meeting of the Society followed immediately after the banquet in the Florida Room of the Citrus Building on Thursday evening when Mr. Frank Holland served as Master of Ceremonies.

Special guest of the evening was Mr. Raleigh W. Edwards, promient dairyman of the Bradenton area whose farm was visited in the course of the pasture tour from the Gulf Coast Station to the Range Cattle Station at the time of the spring (1954) meeting.

President Spencer called for a discussion of the question that had been placed before the Society at the thirteenth annual meeting in Gainesville and subsequently discussed in two meetings of the Executive Committee. Reference is to the changing of the name of the Society from "The Soil Science Society of Florida" to "The Soil and Plant Science Society of Florida" as recommended by the Executive Committee in its meeting at Ona for consideration by the Society as a whole. Because of the importance of this question coming up for discussion at the time of the general meeting it was circularized to the entire membership by sending the following notice to each member by first class postage along with the announcement of the meeting and preliminary copy of the program:

IMPORTANT NOTICE TO THE MEMBERSHIP OF S.S.S.F.

It will be recalled that at the business meeting in Gainesville last January a petition from the Agronomists was read and discussed covering a keen desire on their part that the name of the Society be changed to an extent and in a manner that would be inclusive of their interest in plant work. In accordance with instructions received from the floor at that time President Spencer called a meeting of the Executive Committee at the close of the interim meeting of the Society in Bradenton on April 15. The above matter was reviewed and the alternate name of THE SOIL AND PLANT SCIENCE SOCIETY OF FLORIDA *tentatively selected for consideration. However, due to the importance of this step President Spencer asked four additional members to act with the group on this question, two soils men and two agronomists, and called a second meeting at Ona on April 16. After due discussion the above name was decided on as a good and proper alternate. The vote that followed was strongly in the affirmative that the name of the Society be so changed. It is therefore the purpose of this notice to advise each member that this question will be brought before the Society in the course of its business meeting on the evening of Thursday, December 2, for final decision.*

Secretary

During a floor discussion of the question Mr. Forrest E. Myers of Gainesville took a decidedly negative view of the need for such a change. He was followed by 4 or 5 other members who were about equally divided as to their opinion in the matter. The vote that followed by a show of hands was unfavorable to the recommended change in the name of the Society by about 4 to 3. However, before the subject was dismissed

Mr. J. C. Morcock of Atlanta moved a study be continued of the feasibility and desirability of such a change of name for the Society and that a vote be taken from the entire membership by mail before the time of the next annual meeting. The motion was seconded and carried by voice vote.

President Spencer then asked for reports from the Secretary-Treasurer on membership and finances and from the Editor on publication of the Proceedings.

MEMBERSHIP

As in the past, the list of Honorary Life members and of Sustaining members are to be found at the front of this volume and that of the Annual members in the appendix at the back. For convenience in reference these can best be summarized as follows:

	Annual	*Sustaining*	*Total*
Florida	571	78	649
U. S. (other than Florida)	196	37	233
Caribbean area	122	5	127
Foreign (other than Caribbean)	30	6	36
Total	919	126	1045
Honorary Life Members			11
Grand Total			1056

Among various items for comment in this connection it should be reported that our "Society-wide" membership campaign was a bit of a failure. Too many members simply completed with their own name and address the membership card that was sent to each along with a preliminary draft of the program and returned it with their regular dues whereas their name had been typed on it as "Nominator" for a *new* member. However, there are bright spots in the effort as several new names are on the rolls of the Society as a result of it and we hope more will come in. We also had a letter from Professor L. W. Ziegler of Gainesville asking for 5 more cards as he had 3 members lined up at the time and was expecting to find some more. Naturally we sent not less than 7.

Reference at this time also should be made to the special assistance received in the past from the State Department of Agriculture, Bessemer Properties, Inc., Central and Southern Florida Flood Control District, and the U. S. Sugar Corporation; also to the latter as well as to the Wilson & Toomer Fertilizer Company and the Lyons Fertilizer Company, who, for the past several years, have turned in the names of their technical staff as annual members in addition to the Sustaining memberships carried by the parent companies.

REPORT OF THE TREASURER

As might be expected during a year when two volumes of the Proceedings are published, the present balance is not nearly as bumptious as that reported last year. However, it is given in brief form with the understanding that, according to past procedure, the books will be formally

closed on January 31 and audited at that time, the audited record to be published in the Proceedings. This final report is now set forth as follows:

STATEMENT OF RECEIPTS AND DISBURSEMENTS FOR THE YEAR ENDING DECEMBER 31, 1954

Cash in Banks January 1, 1954		
Everglades Federal Savings and Loan	$2,340.16	
Florida National Bank	5,688.73	
		$ 8,028.89
Receipts—Dues collected and Proceedings sold		5,170.90
Total monies to be accounted for		$13,199.79
Disbursements		
Accounting	$ 25.00	
Office Supplies	86.13	
Postage	325.00	
Printing—Publications	5,458.58	
Telephone	8.75	
Payroll	825.00	
Bank Charges	1.50	
Expenses—Annual Meeting—1953	385.65	
Expenses—Annual Meeting—1954	19.73	
		$ 7,135.34
Cash in Banks December 31, 1954		
Everglades Federal Savings & Loan	$3,622.34	
Florida National Bank	2,442.11	
		6,064.45
Total monies accounted for		$13,199.79

Approved by the Auditing Committee, Dr. Victor E. Green, Chairman

PUBLICATION

The Editor's report is largely one of appreciation to the members of the Publication Committee that was appointed by President Spencer and given the responsibility of preparing the manuscripts for Proceedings Volume XIII for the press as promptly as possible. This committee operated under the chairmanship of Dr. Charles F. Eno and did a very fine job.

In addition to the current volume of the Proceedings the delinquent Volume XI was gotten to and through the press during the year and it is hoped that all who were members in 1951 have received a copy. In connection with the distribution of all volumes of the Proceedings, it should be understood that there is a place on the form that is filed for each member to indicate just what serial number of each volume is sent, this number being imprinted at the upper, right hand corner of the back of each volume.

Further to the above in connection with printing that is in arrears, it is hoped that before the end of the present calendar year the balance of the even more belated Volume VI will be in press. It is about 1/3 set up at the present time. This will close the colossal dereliction of your Editor in this respect with the exception, if he may dig just a bit deeper and find Proceedings Volume V-B, which is quite a difficult mass of transcript dealing largely with soil survey and fertilizer technology problems. It is the further hope of the Editor that, with the approval of the Executive Committee, this second volume of the Proceedings for 1943 can be gotten to and thru the press and distributed during the coming calendar year.

It would seem that one of the best evidences of the strength and purpose that has constantly characterized the growth of our Society is the fact that it has so successfully ignored such a record of delay in the publication of its Proceedings. In another few months all of this should be a thing of the past. In view of the excellent cooperation of the membership and especially of those appointed by the President to assist in getting out the current volumes with proper promptness there would seem to be no good reason for such a delinquency ever developing in the future.

REPORT OF RESOLUTIONS COMMITTEE

A Resolution of Sympathy was read by the Secretary which told of the Society's loss by death of six of its valued members during the year. The reading was followed by a brief period of silence at the request of the President. The resolution is published in full in this volume on page 211.

REPORT OF NOMINATING COMMITTEE AND ELECTION OF NEW OFFICERS

The Nominating Committee appointed by President Spencer during the morning meeting consisted of Dr. Henry T. Harris, Dr. W. T. Forsee, Jr., and Mr. J. C. Morecock. Although the man of their choice became ill at the last minute and actually could not attend the meetings, the warmth of Chairman Morecock's recommendation in behalf of his committee prevailed and Dr. Walter Reuther was elected Vice President of the Society by acclamation, there being no nominations from the floor.

Following the election of the Vice President his predecessor in this office, Dr. Fred H. Hull, automatically became President and assumed the chairmanship of the meeting. President Hull's first act was to appoint Dr. I. W. Wander as chairman of the Publication Committee with each Symposium Leader of the meetings just concluded a member of that committee. This included Drs. J. G. A. Fiskel, Evert O. Burt and J. R. Christie.

There being no other business to come before the meeting it was adjourned at 10:45 P.M. after a call by the President for a brief meeting of the Executive Committee immediately following the close of the business session.

MEETING OF EXECUTIVE COMMITTEE

In view of the absence of Vice President Reuther the meeting of the Executive Committee was very brief and only a few general matters were discussed. It was particularly decided that the Spring Meeting of the Society would be held at the North Florida Experiment Station at Quincy on a date to be selected later by Director W. C. Rhoades and his staff at that Station. As during the past year it was also decided that the occasion of the Spring Meeting would be the best time for a further meeting of the Executive Committee to discuss time, place and program of the next annual meeting and any items of unfinished business that could not satisfactorily be taken up at the first meeting of the Committee.

RESOLUTION OF SYMPATHY

WHEREAS, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come;

NOW, THEREFORE, BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

F. M. CONNOR
Palmetto, Fla.

DR. FRANKLIN K. DAVIS
Auburn, Ala.

DR. DAVID FAIRCHILD
Coconut Grove, Fla.

DR. G. S. HIERS
Philadelphia, Pa.

W. H. KLEE
Jacksonville, Fla.

RAMON M. TRIAS, SR.
Havana, Cuba

Dr. David Fairchild, as snapped at Kampong, his home in Coconut Grove, in 1941, by Wilson Popenoe, after having given the Secretary of the Society a few seeds he had just plucked from an adjacent plant and while telling of their merit, how they should be planted, etc. The immense personal interest and concern indicated in those seeds is so characteristic of the attributes which he showed throughout a long and useful life devoted to plant introduction and improvement that it was felt the picture should be shared with those who knew and loved him for himself and for his remarkably industrious devotion to plant life in its fullest meaning.—R. V. A.

ERNEST L. SPENCER

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1954 RETIRED

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Fred H. Hull	Vice President
Nathan Gammon, Jr.	Member Executive Committee
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